Optimizing the Building Envelope
With a BIM-Based Framework

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**ABSTRACT**

Imagine putting together a puzzle with pieces designed by ten different companies. The building envelope process is like that puzzle: it is made up of an aggregate of multiple designs coming together for the first time, on-site. Building information modeling (BIM) puts all the pieces together virtually so that multiple design elements come together on-site with design mistakes and oversights identified and corrected. In 2015, Zero/Six collaborated with Hensel Phelps to assemble the pieces in a BIM framework to coordinate shop drawings for a large facility. The speakers will discuss how to design the building envelope through BIM workflow processes, organize the model by trade, conduct project sequencing, and generate quantities directly from the data. BIM allows designers to put the building envelope puzzle together before dumping all the pieces out of the box.

**SPEAKERS**

*William Coltzer, Jr., AIA – Zero/Six Consulting, LLC, Galveston, TX*

The son of a contractor, BILL COLTZER, JR. grew up on construction sites. He is the founder of his firm. He graduated from Texas A&M with a degree in environmental design. Coltzer’s understanding of construction, architectural training, and real-world experience have resulted in a unique perspective. He believes a greater understanding of key concepts can revolutionize both performance and expense on any job.

*Christian Ozbun – Zero/Six Consulting, LLC, Galveston, TX*

As director of simulations, CHRISTIAN OZBUN, RA, leads his firm’s modeling services and is the resident BIM specialist. Prior to joining Zero/Six, he was involved in a broad range of project types and work scopes within the AEC industry. His experiences include construction management, BIM, energy analysis, forensic architecture, construction administration and documentation, software development, and as-built documentation of some of the U.S.’s largest buildings.
ABSTRACT

Imagine putting together a puzzle with pieces designed by ten different companies. The building envelope process is like that puzzle: it is made up of an aggregate of multiple designs coming together for the first time on-site. Building information modeling (BIM) puts all the pieces together virtually, so that design mistakes and oversights can be identified and corrected.

In 2015, Zero/Six collaborated with Hensel Phelps to assemble the pieces in a BIM framework to coordinate shop drawings for a 432,671-sq.-ft. facility. Numerous architectural and structural drawings multiplied the potential for discrepancies both before and after construction. By combining the envelope drawings and structural model into an intelligent 3-D design, we were able to identify issues that would have been costly to remedy once the pieces came together on-site.

Our research presents an overview of BIM for engineers, architects, and construction professionals to optimize the building envelope through BIM workflow processes, organizing the model by trade and project sequencing, and generating quantities directly from the data. BIM allows us to put the building envelope puzzle together before dumping all the pieces out of the box.

Learning Objectives

1. BIM Workflow Processes.
   Learn how BIM is a natural extension of the construction process.

2. Project Sequencing: Not only must the BIM take into account each contractor’s scope. Architectural drawings look mainly at design intent (how it looks) and where components need to be located. A coordination model looks at which contractor will be installing each specific item.

4. Generating quantities directly from the data: Since each item has embedded data in it, it’s possible to get a material quantity generated directly from the model so each subcontractor knows how much material they can expect to use.

INTRODUCTION

The human experience with technology is quite ambivalent. There have always been two prevalent views on new technology: It’s the great panacea for all the world’s ills; and, at the same time, many believe that technology will turn on us and we will find ourselves trying to survive in some kind of post-apocalyptic world.

For about four or five generations now, we’ve imagined technology as being the solution to all our problems by leading us into some kind of futuristic utopia with flying cars, robot maids, and computers that automate our day to the point where we only have to work four hours a week. How many people are down to four hours per week?

In 1962 at Rice University, President John Fitzgerald Kennedy made the statement, “We choose to go to the Moon in this decade and do other things, not because they are easy, but because they are hard; because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win.”
I do not believe that in his wildest imagination, President Kennedy could have ever imagined how far technology was about to take us. Technology has taken us to staggering heights and has undoubtedly made shopping, getting information, and even finding a date much easier. President Kennedy undoubtedly would be proud of our accomplishments, but despite the technological leaps and bounds we’ve made, we seem to be, on average, working longer hours. Online shopping has been a source of fraud, a lot of that information at our fingertips is incorrect, and as for the date, well, the date won’t be part of the slide show accompanying this paper.

I am not here to argue the pros and cons of technology; I am here to argue that technology is a tool, just like a wrench or shovel. It can make things better, it can hurt you if you're not careful, or it can stay in the garage and never be used. I believe it is time to pull BIM out of the garage for more purposes and put it to work for the building envelope (Figure 1). BIM won’t take us to the moon, but BIM can be the next best thing to a flying car if you learn how to use it.

While BIM stands for building information modeling, coordination is the term I want focus on because that is what BIM does for us; it coordinates a project in a way that the oversights are corrected on paper beforehand rather than on-site, often saving tremendous time and expense.

I doubt anyone would argue that BIM has not made the production of construction documents more streamlined (Figure 2), but I still cannot say with confidence that it has made the final constructed product more coordinated, more cohesive, and more buildable. After all, if BIM is just a tool, then saying that BIM will make an architect’s documents coordinated is like saying that a good torch will make a roofer lay down a good modified-bitumen membrane. The end result of one using a tool to accomplish a purpose is really contingent on three things: the skill of the user with that tool, the quality of the tool, and the thoroughness of the process. It is the process I want to focus on.

In large commercial projects, architects generally spend long exhausting hours putting together a multitude of moving parts with their consultants to produce a design that is generally well thought out, at least at a conceptual level. I am not going to blame the woes of construction sequencing on the skills of the architects. After all, general contractors are paid good money for solving the means and methods.

If we have good architects, and we pay well to have good contractors, one might then point the finger of blame towards the tool itself, BIM or digital design in general. There is no doubt that BIM makes our job easier, but it could be argued that the ease of producing a 3-D model is creating cut-and-paste architecture that is only buildable on paper. I’ve heard contractors sarcastically quip, “If you can draw it, you can build it, right?” It may be the reality that some architects produce bad work, but it is not logical to blame a good tool for poor workmanship. We all know that many great buildings have been constructed after being manually drafted. Logically, if we are operating with sharper tools, then sequencing and coordinating exterior envelope trades together should be easier.

Therefore, if we have smart architects, smart contractors, and great technology, then why are we still struggling to create an exterior enclosure from a set of construction documents? One can only logically deduce that if the difficulty doesn’t arise from the operator or the tool, then it must be coming from the process (Figure 3).

The current process of taking a building envelope from an idea to reality follows as such:

- Design it.
- Create construction documents.
- General contractor divides construction documents up by trade.
- Each trade produces its own shop drawings.
- The general contractor coordinates the drawings together.
- Construction and assembly of the envelope follows.

In short, the envelope starts out life in the construction documents as one cohesive BIM that is coordinated, but not yet
Figure 4 – Workflow processes.

Accurate. It is then given to each trade, and separate sets of drawings are produced that are now accurate, but are no longer cohesive; thus, we come to see that the process has a flaw (Figure 4).

This process flaw is why we need to pull BIM out of the garage for the building envelope: The principal advantage of BIM technology is its ability to take disparate components that make up the exterior envelope and assemble them virtually before they become a reality. BIM brings the shop drawings together in such a way that now they are both accurate and cohesive with the original construction drawings. So, if smart architects are able to come back and reassemble the exterior enclosure based on the shop drawings in a collaborative manner, the process works.

If you performed a Google image search for “BIM coordination,” you would see colorful images of HVAC ductwork, sprinkler pipes, electrical conduit, air handlers, and many other pieces of equipment installed by the mechanical, electrical, and plumbing (MEP) trades. One thing you won’t see when scrolling through the images is a composite model of exterior envelope trades. To my knowledge, nobody has ever attempted to create a composite envelope BIM. So in April 2015, we found ourselves sitting in an exterior envelope preconstruction meeting for the new, half-million-sq.-ft. University of Texas Engineering Education and Research Center (EERC). When they asked who could create a composite building envelope BIM, we raised our hand. Originally this document was intended to be a virtual clash detection tool that would find issues. As the process evolved and the lack of cohesiveness in assembling components became evident, we switched gears and instead provided to Hensel Phelps and the University of Texas a giant change order that was ultimately the basis of construction for the entire exterior envelope. In the end, this was much more convenient for the construction team because they were able to spend more time managing construction and much less time sending the architect requests for information (RFIs). This new BIM had all the answers (Figure 5), so questions rarely arose.

WORKFLOW PROCESSES

Creating a BIM, just like building a new building, has to follow a specific order—a workflow process, if you will. Before the coordinator can model the envelope, they must start with the contract structural drawings and create an accurate structural model from which the virtual envelope components must be modeled. The EERC is a concrete building; therefore, the embeds had to be coordinated prior to pouring concrete. Some of the first discoveries made
in the coordination effort happened when the structural model and the architectural model were overlaid. Immediately, our firm and Hensel Phelps noticed that we had beams and slabs running through curtain-wall systems, slab edges that jogged in and out on a vertical wall, expansion joints that didn’t line up, and various other anomalies where structural items were in conflict with the building enclosure systems. These issues were brought to the forefront early on, and the design team was able to make revisions to the contract documents without any trouble. By doing this, Zero/Six was able to catch several major issues before even opening the shop drawings.

PROJECT SEQUENCING
Once your virtual foundation and superstructure has been established, the coordinator can then begin modeling each trade. Once again, with nine trades, as we had on this particular job, one must ask themselves, where do I begin? Zero/Six has found the best course of action is to follow the same sequencing that will take place in the field. The best part about operating in a BIM (Revit® in this case) environment is that there are phasing tools that can be utilized within the virtual environment to show scenarios, such as one floor being constructed at a time, one trade being installed at a time, demolition, or a large building being constructed in phases. The phasing tool was quite useful for EERC, because the projects had many different envelope trades coming together, and often, the contractor was forced to install components in a non-typical fashion. Our firm’s model was able to capture these occurrences, and the contractor was able to use the BIM as a visual construction-scheduling tool (Figure 6).

The BIM coordination process goes beyond design and encompasses means and methods. It differentiates itself from a generic 3-D model in that it can simulate the project being built from the ground up, piece by piece. Additionally, each RFI and change order can be treated as a phase, allowing the construction team to see a before and after snapshot of each change made to the envelope. For example, at the beginning of the project, we had to move a few structural items due to conflicts with the approval of the structural engineer of record. Since the envelope components are attached to the structure, getting the structural frame correct at the beginning was crucial. Also, since our firm is an envelope consultant and not a structural consultant, we wanted to be very careful when moving structural items. By using the BIM phasing tools, we were able to carefully document each change that departed from the original design by correlating it to its respective RFIs (Figure 7).
ORGANIZE BY TRADE

The EERC had 12 different subcontractors working on its exterior and even more sets of drawings that had to be combined to create a composite building envelope model. Our firm made sense of all this by organizing the model by trade or subcontractor. We utilized the “work sets” function in Revit to isolate each trade into a separate layer. Using this work sets function on the EERC model, we were able to turn certain components on and off in the model similar to the way AutoCAD works. For example, the EERC is a stone-clad, cavity wall building with a concrete masonry unit backup wall. The construction team could turn off the stone veneer and see how flashing, masonry clips, and ornamental metal clips are tied into the drainage plane (Figure 8).

The EERC Composite Shop Drawing Model articulates the envelope layer by layer similar to the way that actual construction is sequenced. This approach to creating a BIM enabled our firm to collaborate with subcontractors at preconstruction meetings more effectively by using the model as a visual tool. During biweekly meetings, the construction team was able to sit around a table, pull up the model on a screen, and come up with solutions to observed conflicts. More often than not, issues were resolved in these meetings, and envelope-related RFIs were generally written as mere formalities because the team had already reached a solution in the meeting. Not only did the BIM coordination process cut down on the number of RFIs issued, it also consolidated all of the changes made via RFIs into the model.

One of the woes of coordinating construction issues via RFI is that once the RFIs have been answered, the construction team now has to coordinate those same RFIs (Figure 9). The standard coordination problem, without BIM, solves one problem and creates another. The contractor is generally left constructing the building on RFIs. This is especially true when a building envelope is particularly complex and the shop drawings diverge significantly from the architectural drawings. However, with the use of BIM, the construction team can incorporate changes made during construction into the 3-D model (Figure 10). The changes can be incorporated via phasing, labeling, or work sets. The BIM environment is a very flexible environment for organizing changes. Not only can the construction team use BIM coordination to mitigate the number of RFIs issued, they can more importantly utilize the technology to prevent construction mistakes caused by the lack of coordination.

I’m a firm believer in the old adage, “An ounce of prevention is worth a pound of cure.” This statement rings especially true in a large commercial project where one mistake multiplied can cost millions. One might compare envelope BIM coordination to going to the dentist. Going in for a teeth cleaning costs money, but it’s a lot cheaper (and far less painful) than a root canal. Similarly, paying for an extra service like BIM coordination will cost some money, but the cost likely won’t compare to the...
remediation costs of chipping concrete or refabricating doors that don't fit their rough openings. At the end of many jobs, there are construction managers wishing they had a time machine and a BIM coordinator. BIM can be that time machine if its features are utilized to manage the workflow, sequence, and organize the project by trade.

**GENERATING QUANTITIES**

Additionally, BIM can be useful in a design-build scenario where pricing from the contractor is done during construction. Revit, like most BIM tools, will produce quantities and schedules right from the model with far greater accuracy than taking measurements from a drawing. It's also useful after construction is underway in that the generated quantities can show numbers against quantities previously bid. The contractor can then adjust by crediting the owner or taking from contingency built into the project.

**RECORD DRAWINGS**

After the project, the building envelope model can be kept by the owner for record drawings. Facilities can then use the BIM for future maintenance and repairs without the unknowns of what is underneath a roof membrane or behind a wall cavity.

**COLLABORATIVE EFFORT**

The University of Texas EERC project was not a pain-free job; however, many of the potential construction errors were dodged via BIM coordination tools and subcontractor collaboration. Through collaboration, we were able to get out in the front of both shop fabrication and on-site erection. For example, the EERC used unitized curtain wall systems almost exclusively. These systems arrive on-site premanufactured and cannot be modified. There was a condition on the project where there were numerous unitized curtainwalls above a modified-bitumen roof curb. The shop drawings provided by the curtainwall contractor showed the curtainwall sitting right on the roof system with insufficient clearance to terminate the roof edge with a counter flashing. By using BIM in our envelope consulting to virtually construct the project, Zero/Six was able to identify the issue, propose a solution, and bring the contractors together so that a revision to the shop drawings could be made prior to the manufacturing process.

If all team members are engaged, coordinating the project virtually will not only make construction flow smoother and make envelope systems detail together seamless-
ly, but it also can improve the project’s aesthetic appearance. Generally, the difference between a mediocre building and a handsome building is the quality of the detailing (Figure 12). The late architect Ludwig Mies van der Rohe said, “God is in the details.” It’s a self-defeating exercise to spend a large sum of money on a travertine façade only to have the detailing around the windows go poorly because of a lack of coordination.

Similar problem-solving, with the help of the architect, took place on the EERC coordination effort to meet the design intent of the project. There was a stainless steel break metal slab edge detail that, if installed as indicated by the shop drawings, would have ruined the appearance of the façade. By doing some 3-D investigation, the issue with the shop drawings was discovered. With help from the architect and subcontractor, a revision was made to create an easier-to-assemble detail that improved the final appearance of the project.

As previously discussed, BIM software is a tool that can work well if used in the right process. A pivotal importance is placed on the user. It’s important that the user be familiar with the software, but that is a minimum requirement. For the process to work well, there must be collaboration between the coordinating parties, BIM operators, subcontractors, and the design team. Our firm would never be able to successfully coordinate the EERC if we didn’t get feedback from the subcontractors. In order to model certain components so that they fit into the virtual envelope assembly, coordinating teams need to know what the subcontractor can manufacture. For example, while coordinating the limestone panels on the EERC, the masonry subcontractor informed us that while the stone pattern appeared to be random, there were only three primary stone widths on the building façade. Had Zero/Six changed the stone to make more room for other components, the price for ordering and installing the stone would have gone up significantly. Without participation from all parties, the coordination effort would not have been a success.

Just as it is important to have a good team for BIM coordination, timing is also key for a successful effort. It is imperative to start BIM coordination of a project as soon as shop drawings are developed. It is especially valuable for big projects to begin exterior envelope BIM coordination on the mock-up (Figure 12). Many of the issues that will be encountered on a project can be solved and avoided on the mock-up, and the quality of the final BIM will be improved by working them out first in virtual reality on the mock-up (Figure 13).

During construction of the EERC visual mock-up, our firm produced a BIM. Details and Revit families were taken from the mock-up model and put into the full-sized model, saving a great deal of time in building the final BIM. Because we were brought aboard to do BIM coordination as shop drawings were coming out, conflicts were discovered virtually well ahead of the conflicts becoming a reality.
CONCLUSION

In summary, BIM technology is just a tool, and the opportunity Zero/Six sees on the BIM horizon is creating virtual envelope assemblies before the occurrence of real envelope problems. Keep in mind: BIM coordination can’t be done prior to shop drawings (Figure 14) because there are too many moving parts in today’s envelope assemblies to get the exterior enclosure right before the subcontractors are involved. The role of the BIM coordinator is like that of a conductor in an orchestra. The BIM coordinator doesn’t play any instruments. He must rely on the subcontractors to provide the music that is the building envelope.

Last August we were walking the job site at the EERC building with the construction manager, when he mentioned that the building had gone up so smoothly that now that they were in the roofing stage, he wished he had asked us to do BIM coordination on the roofing systems, as well. Take advantage of BIM; it will make you look good on the job site (Figure 15).

So on that warm September day at Rice University when President Kennedy spoke those immortal words that took us to the moon, it also launched the technology we are benefactors of today, as he explained: “We set sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be used for the progress of all people.”

The tools we use to construct the projects of tomorrow will no doubt continue to be sharpened by advances in technology. The question is, “With that new knowledge, are we benefitting all parties involved in these undertakings?”