WHAT in the WORLD is BIM?

By Matt Dupuis

INTRODUCTION

On any given day in the roofing industry, we swim in our own little section of the pond, oblivious to changes in the construction industry as a whole. But every now and then, we probably need to poke our heads up and take inventory of what is going on.

Currently, there is a large shift taking place in the architect/engineer/contractor (AEC) community. This shift is at a very fundamental level. It is not as simple as a new technology or a new product. It is a paradigm shift in the way we conceive, design, bid, build, and even operate buildings. This change revolves around two terms and what they entail. The first term is "building information modeling" (BIM). BIM is typically considered a piece of software or a collection of software accommodating the design of a construction project in three dimensions. The other term is integrated project delivery (IPD). The simplest explanation for IPD is that it is a way to deliver a project where all parties, such as the architect, engineers, owner, general contractor, and even major subcontractors sign a collective agreement to share the risk and rewards of a collaborative building effort.

WHAT IS BIM?

So what is BIM, and why do we even need it? Well, why the AEC industry needs it is easier to show than explain. *Figure 1* is a graph from a study done by Dr. Paul Teicholz[1] from Stanford University. This graph shows the efficiency of other industries against that of the construction industry. The simple interpretation of the graph is that the construction industry has actually decreased in efficiency over time! What happened there? This should not be a shock to anyone, but as our buildings have gotten more complex, so has the way in which we design and build them. Things like change orders, requests for information (RFI), architects' supplemental instructions (ASI), code approvals, and construction errors have slowly burdened the design and construction process.

So what does BIM do to fix this? I can remember when, as a kid, I went to see my father at his engineering office. This would have been in the late '70s and very early '80s. I can still remember seeing drafters and engineers hand-drafting roof plans, construction details, and the like. Somewhere around 1982, my father and his then-partner plunked down some $20,000 to buy a CAD station, CAD software, and a plotter. Why? It was new and expensive technology, but it promised to improve efficiency, provide a better product to clients, and hopefully make a decent return on investment (ROI). So what did this change in how we design a building and create construction documents? Nothing!

Fast forward to 2005. Designers still produce construction details, elevations, plan views, schedules, specifications, etc. Yes, they use the computer to generate all these construction documents. But the fact is, designers still produce a giant roll of drawings and voluminous specification manuals to build even a modest-sized structure. Those in the AEC industry have all seen situations where a change was made to one drawing – say the location of several rooftop HVAC units – and someone didn't make the change in a penetration detail or a cross section through said area. This typically leads to change orders, construction errors, delays, possible increased cost for the owner, or loss of profits for the contractors. So with current design and construction techniques, there is no real way to bridge these individual "silos" of information.

Wouldn't it be easier if all these individual drawings, specifications, and other information were linked in real time? What

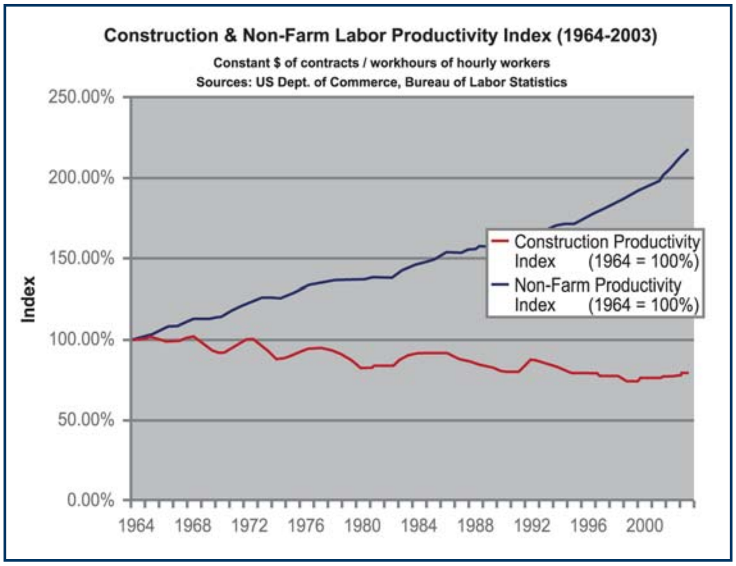


Figure 1 – Results of a study conducted by Dr. Paul Teicholz[1] from Stanford University. The graph shows a marked decrease in the efficiency of the construction industry, despite our advances in technology.

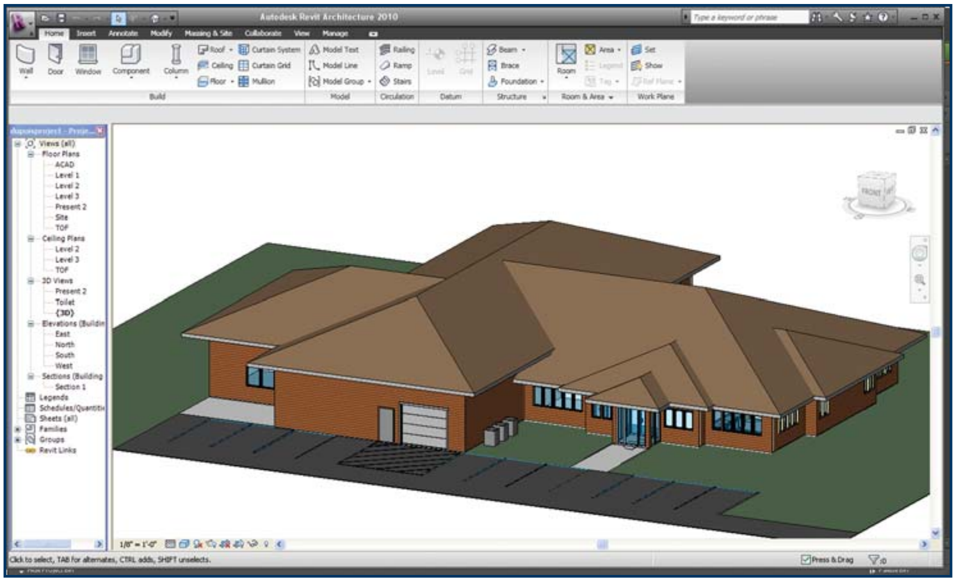


Figure 2 – Shown is a screen shot of Revit Architecture 2010 in use. Make any changes in this view, and the underlying database is altered, instantly updating any related cross sections, elevations, plan views, etc. This is a simple small office and laboratory; structures the size of athletic stadiums and skyscrapers can be, and are, modeled in this same program.

if the architect changes the thickness of the roofing membrane from 45 to 60 mils? Wouldn't it be perfect if this change instantly migrated to all the drawings, the specifications, and even the estimating? This is what BIM is capable of doing!

In its simplest form, BIM is a database file. It contains all of the spatial, relational, and parametric data to define a complete structure. Each of these data types is special and deserves a brief explanation.

- **Spatial Data –** Basically x, y, and z points for the start and stop points for beams, columns, floors, HVAC ducts, carpeting, and any other object in the structure.
- **Relational Data –** A simple concept, this type of data allows objects to "know" how they are related or connected to other objects in the structure. E.g., if we move a wall, the floor system moves with it, remaining attached and growing and shrinking as necessary.
- **Parametric Data –** This data type is the big advancement with BIM. The parametric data point is more plainly known as a parameter. These parametric data can be any types of data we choose: R-value of insulation, manufacturer's name, product model, date of installation, serial number, even a PDF copy of the warranty could be stored as a parameter.

So a BIM model or file is a collection of data. How do people view it? How do they design with it? How do they build with it? As previously stated, they use a software package or family of packages from BIM software vendors. Some examples of these packages are:

- Revit Architecture from Autodesk
- Revit Structure from Autodesk
- Revit MEP from Autodesk
- Tekla Structures from Tekla
- Bentley Architecture from Bentley
- Bentley Structural from Bentley
- VICO from Vico Software
- Navisworks from Autodesk

Figure 2 shows a screenshot of the Revit Architecture 2010 package with a 3-D view of a sample structure. Take note that each of these packages has strengths and weaknesses. Just as in roofing, where no membrane or system is ideal for every application, the same applies with BIM packages. As of this writing, the Revit family of software from Autodesk has become the dominant package in the AEC industry.

BIM packages can be relatively expensive to implement, as a suitable computer and software can run in excess of $10,000 for a basic setup. But they are being used more and more every day. Why? Because there is an ROI to be made, and this is the most basic of good business principles. Let's look at a few of the major advantages of designing and building with BIM.

- Design efficiency
- Reduced or eliminated construction errors
- Automated estimating
- Integrated scheduling
- Automated CAD/CAM
- Operations and maintenance applications

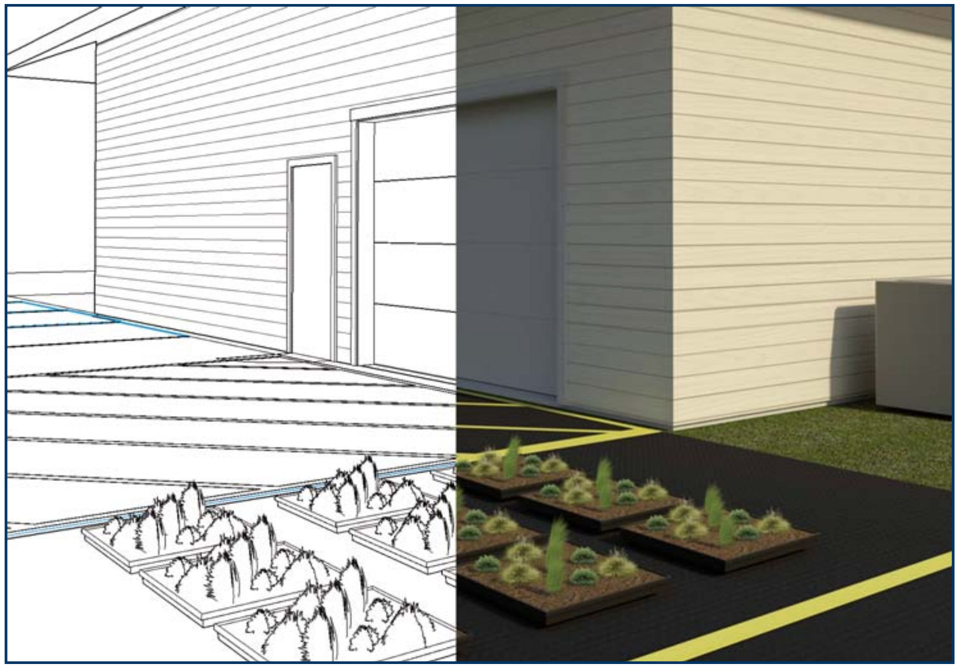


Figure 3 – Using the model in this figure, a simple grid of green roofing trays is placed in the parking lot. Obviously, they don't belong in the parking lot, but the figure shows the capability and power of current BIM packages. Both sides of this figure use the same camera location. The left half of the figure is what is seen while designing in real time, while the right half is a fully rendered version with shadows and textures. The ability to render images is built into many BIM packages.

DESIGN EFFICIENCIES

With traditional design methods, the architect will draw plans and pass them off to the structural engineers, electrical engineers, plumbing designers, fire protection designers, etc. These groups will have to redraw the building in their own design packages. For example, the structural engineer will have to enter/design the structural system in his firm's own structural design package. This represents a redundant entering of the same data and a loss of efficiency. Beyond this, each of these designers creates his or her own stack of paper and documents.

When using BIM in the design process, the data file can be shared amongst all of these parties, even simultaneously! The structural engineer can be virtually adding structural steel to a penthouse while a mechanical engineer is designing HVAC ducts on the first floor. In addition to adding objects into the building, engineers are beginning to see analysis packages that will read and interact with the data in the BIM file. For example, RAM Structural System will read a Revit file, analyze the structure, make recommendations about the design to the engineer, and then make any or all of the changes back to the BIM file.

Structural analysis packages are not the only softwares leveraging this capability. A current push is for energy analysis packages to read the BIM data and analyze the energy usage or carbon footprint of a building. It can then give options for design changes that will improve energy usage. For instance, it will say that adding X amount of R-value to the roof will save $Y of energy per year. This allows owners and designers to quickly assess and make decisions about the energy aspects of a design. These packages go as far as to suggest changes in the building's orientation to maximize or minimize solar loading and artificial light usage.

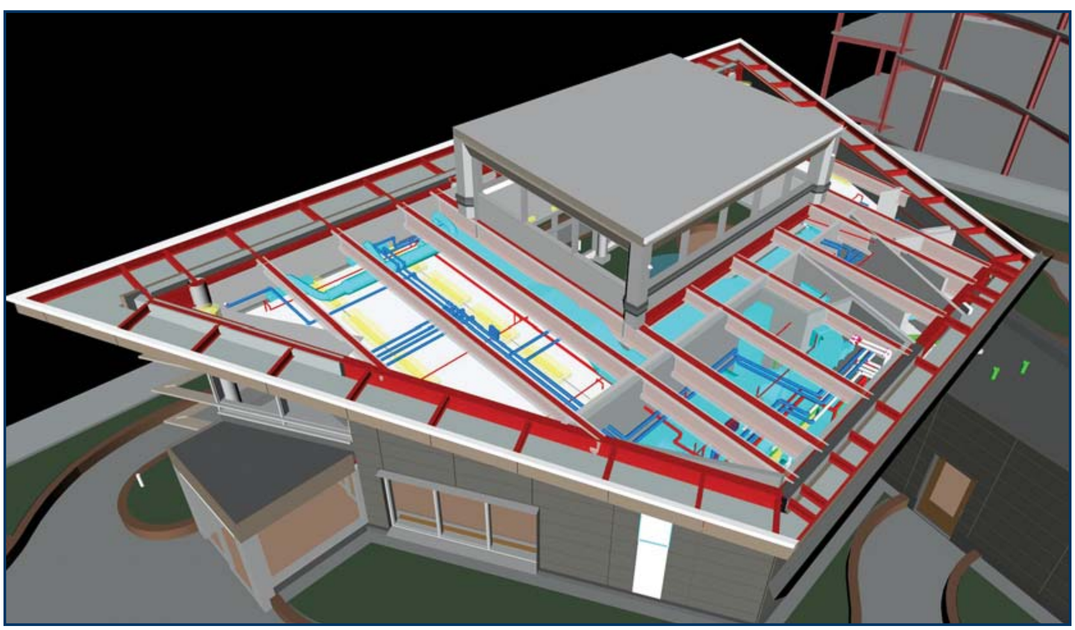


Figure 4 – With a few clicks of the mouse, a specific view can be generated by a BIM package. Here, the roof system and deck were made transparent. Now the underlying structure, mechanical, electrical, plumbing, and fire protection are clearly visible. Courtesy of M.A. Mortenson Company, Minneapolis, MN.

REDUCED OR ELIMINATED CONSTRUCTION ERRORS

Imagine building something the size of a skyscraper without any construction errors or change orders. With traditional design and construction techniques, this would be a dream. With BIM, the computers will analyze the BIM model and identify any "clashes" in the design before a single shovel of dirt is moved. A "clash" can be

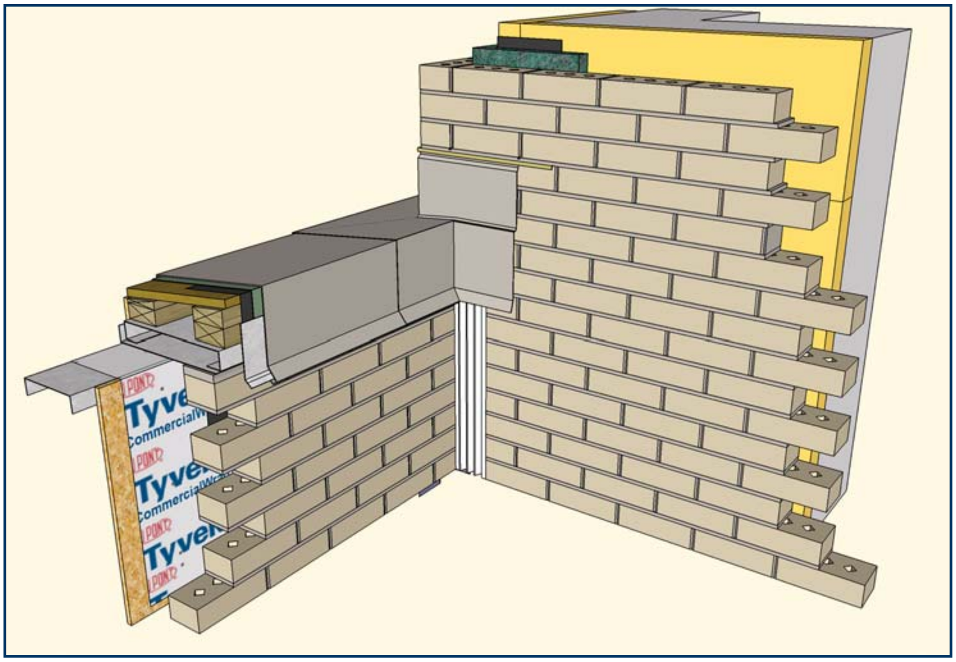


Figure 5 – 3-D details such as this will eventually become commonplace. Currently, BIM packages do not produce this level of detail without special effort and skill. A BIM specialist or "guru," as they are known, can produce a detail such as this almost as fast as a traditional drafter could produce a 2-D detail. The advantage of the BIM model is not only the level and amount of visual information conveyed but also the capability of the program to utilize the information now in the database to instantly cut a 3-D cross section through this wall as shown in Figure 6. Courtesy of M.A. Mortenson Company, Minneapolis, MN.

loosely defined as an area of space where one object intersects or "clashes" with another. A clash can be a drainpipe running through a structural column, an HVAC duct dropped too low and exposed through the ceiling, or even a roof drain hitting a bar joist. All of these things and more can be identified, discussed, and corrected before construction even begins. Traditionally, an architect, an engineer, the general contractor, and two or three subcontractors are standing around looking at one of these "clashes" during construction, discussing what to do about it. This wastes time and money.

ESTIMATING

Estimating a rectangular roof area is a fairly straightforward exercise. How difficult is it to estimate the square footage of an irregularly shaped roof? A barrel roof? A truly unique shape like a Frank Ghery design? Are you sure every roof penetration was counted? Did someone miss a drain?

All of these issues cost money to do take-offs and estimates. All of them have the inherent risk that someone miscounted or miscalculated. A contractor can lose his pants in a hard bid situation, and a consultant who underbudgeted looks very bad to her client.

With a few clicks of a mouse, a BIM package can do precise take-offs. The area of a roof section can be ascertained to the tenth or even hundredth of a square foot, regardless of shape or size. The number of roof drains, lineal feet of flashing, and even the area of a parapet cap can be displayed by the computer in seconds. All of these "quantity extractions," as they are typically referred to, are precise and given in real time. If the building design changes, the quantities are instantly changed. If roof slope is changed by the architect, the computer will update quantities on the fly, as changes are made.

In its current form, this process is not a magic bullet…yet. As an example, labor costs, labor production rates, and weather factors cannot be identified and factored in by the BIM packages. Basically, the BIM package will tell exactly how much membrane will be needed, but it will not tell the time and cost to install it. Some of the larger general contractors are trying to tackle this issue with the major trades. From decades of experience, they know productivity and costs associated with concrete flatwork, for example. They know, for instance, that a crew of six can produce 10,000 sq ft of 6-in slab per day. They can enter this information into a spreadsheet or custom estimating package and then combine it with the quantity extractions from the BIM model. This will provide a fairly solid estimate for a project in minutes, not days. But as you might guess, upper management at these firms is not ready to bid a job solely on these numbers…yet.

SCHEDULING AND COORDINATION

This topic alone could have a BIM article dedicated to it. However, it should suffice to say here that it is a large area of interest and activity for general contractors. A BIM package called Navisworks from Autodesk is the dominant tool used here. Navisworks is known for being able to combine multiple file types from different design areas/packages into one complete model – for instance, 3-D CAD from HVAC, BIM from the architect, 3-D CAD from the structural steel fabricator, BIM from the structural engineer, 3-D CAD from the plumbing designer, etc. Once combined, they can be viewed in 3-D, and a clash detection run, identifying any conflicts in the building before a single shovel of dirt is turned. In addition, each object can then be assigned scheduling parameters (start time, completion time, phase of construction, etc.).

If there are delays in construction, a few modifications in the program instantly migrate to all the objects and shift the schedule. So not only can the software show a Gant chart or the like for the schedule, it can also see the schedule/construction in 4-D, the fourth dimension being time. The software can show construction at two weeks, two years, or any point in between. This is a huge leap visually, as the construction team was previously only able to talk about how a building would go up; now they can see it, too.

CAD/CAM

The spatial 3-D data contained in the BIM model are a big advantage for fabricators. The data can be directly fed into fabrication programs and machines. This all but automates the process of fabricating items such as structural steel and HVAC ductwork with robotic cutters, benders, and CNC machines.

One large HVAC contractor from Chicago reported that his firm feeds BIM data directly to the fabrication shop with minimal human interaction. The structural steel for the famous "Birds' Nest" stadium from the 2008 summer Olympics in China was all fabricated this way. The structural steel was produced in an on-site fabrication shop in an automated process that used the BIM data.

OPERATIONS AND MAINTENANCE

During the handover of a new building to its owner, the latter typically receives a large roll of plans and a stack of three-ring binders with all the owner's manuals and spec sheets for the building components. These drawings and documents usually find their way into a storage room, empty closet, or worse – are rarely, if ever, to be seen again.

As previously mentioned, with BIM, the owner can be given a single digital file with all the information that normally would be contained in the traditional paper documents. But now this information is in a digital format that can be leveraged by property managers, facility managers, and even third-party service providers to operate, organize, and maintain the building.

For instance, the roofing industry currently uses stand-alone computer programs or good old three-ring binders to help its clients manage their roof assets. In the near future, these programs should evolve to merely become an interface to view, edit, and "push" reports. A report "push" is to have the interface utilize the information in the BIM to populate and provide computation data for whatever type of report is desired. Reports such as leak history, repairs, and warranty claims can be pushed from parametric data about the roof in the BIM mode.

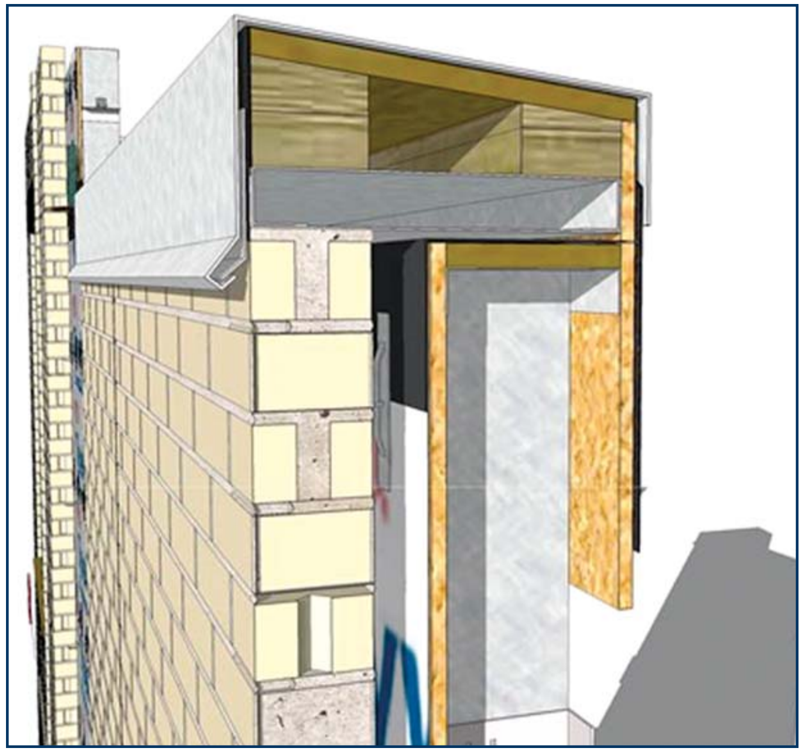


Figure 6 – A cross-sectional cut through the wall in Figure 5. It takes a skilled and experienced BIM modeler to produce this level of detail. But as the BIM software advances, the effort required to produce BIM details should decrease, as well. Courtesy of M.A. Mortenson Company, Minneapolis, MN.

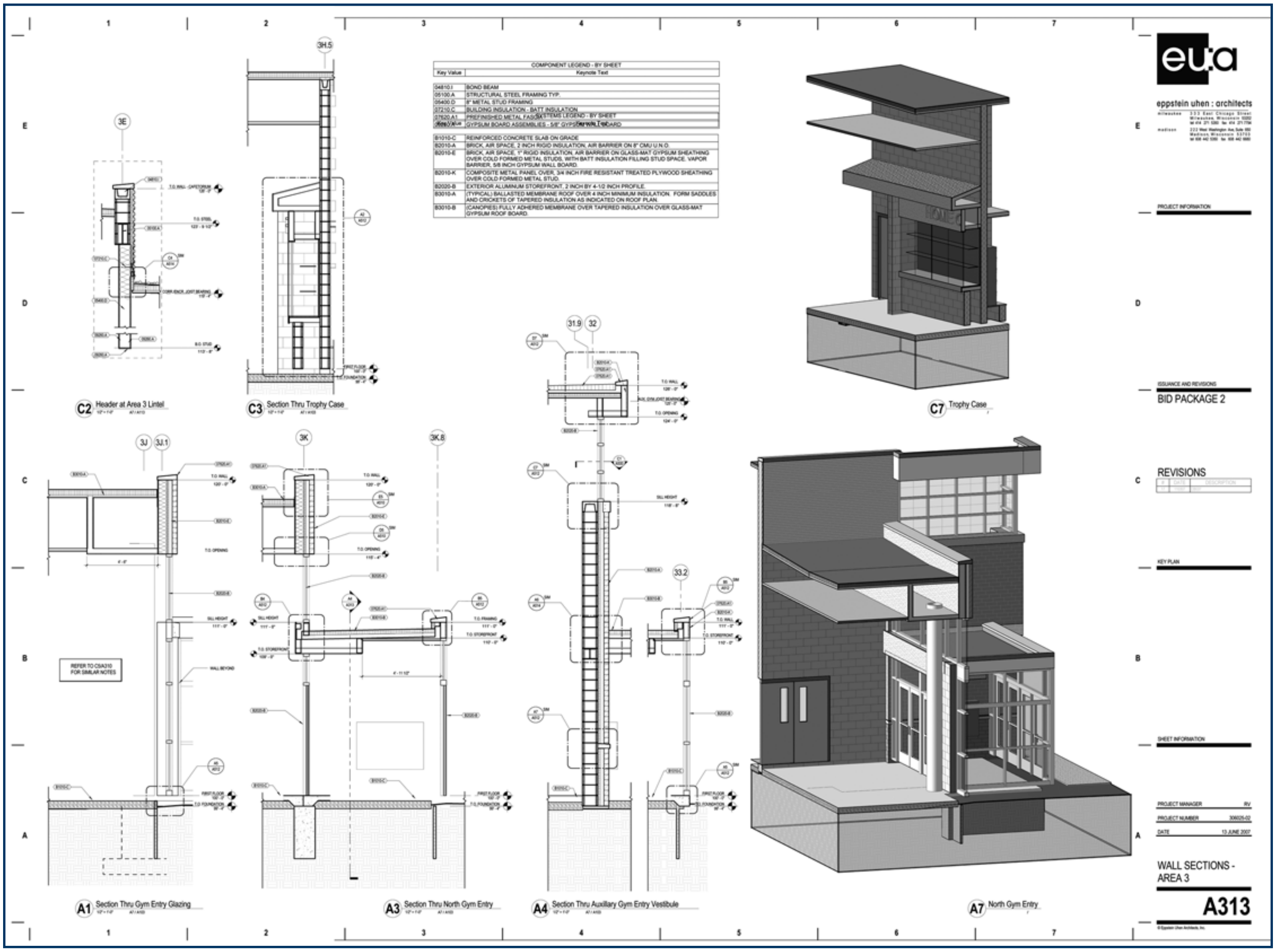


Figure 7 – This shows a typical 2-D sheet from a designer using BIM. This would be an example of a sheet that could be used by workers in the field. Note the generous amounts of extra information conveyed by the 3-D cross sections, such as footing locations, wall intersections, etc., that normally would require multiple sheets to convey, if it were even possible. Courtesy of Eppstein Uhen Architects, Milwaukee, WI.

However, the operations and management (O&M) portion of the BIM picture is still under development. Currently, there are no commercially available software platforms that are able to fully utilize a BIM model for O&M. There have been reports of some custom packages for, say, keeping track of beds and equipment in a hospital. But several major software vendors report that they are working diligently on O&M packages. What these packages' capabilities for roofing will be is changing with every software release. Stay tuned.

INTEGRATED PROJECT DELIVERY (IPD)

Let's loop back to what was said about the inefficiencies inherent to design-bid-build construction. Basically, no one shares information. The architect and designers make paper plans and specs. The contractors make paper shop drawings and schedules. In the end, typically, the owner receives "as-designed" plans and specs, rarely "as-built" designs. Lest we forget, the mountains of contracts with tons of legalese about whose butt is in the ringer when things don't go right has a century of construction litigation history to back it up!

When a construction project uses BIM, the project participants can use a project delivery method called IPD. IPD is all about sharing information and risk. The simplest explanation is that all the parties in a construction project (architect, engineers, contractors, and owners) sign a collective agreement to share information (BIM and 3-D models) – and, hopefully, the risk as well. They win as a group and lose as a group.

In our current litigious society, there is considerable resistance to risk sharing (as opposed to risk allocation) in the construction industry. But to date, the projects and companies that have gone down the BIM road have succeeded in spades. This is not to say the process ensures success, as there have been several notable legal cases involving BIM. While not nearly as prevalent as our design-bid-build contracts and low-bid procurement contracts, standard-form AIA and AGC documents have emerged that attempt to standardize IPD and the use of BIM in construction.

At the offset of this article, it was suggested that we in the roofing, waterproofing, and exterior walls industry need to poke our heads up every now and then to see what is going on in the AEC industry as a whole. What is happening in BIM? What can you do about it? What should you and your firm, as a professional entity in this industry, be doing about it to stay competitive? My suggestions would be:

CONTRACTORS

At this point, capital costs and training really won't give a return on day-to-day operations. Continue doing business as usual for now. However, keep your head up and ears open when working on larger projects with larger general contractors. It can be all but guaranteed that they are using BIM in some form or another on a daily basis.

That aside, Structural Research Inc. (SRI) has consulted on more than one project already in which the roofing contractor itself was using BIM or was being required to use it on a contractual level with the general contractor. Be assured these were very large construction projects with some of the largest general contractors in the country. Uncommon, yes; but expect it to slowly trickle down to smaller projects.

On the more mainstream construction projects, be aware that if BIM is being used by even the general contractor alone, there are tools the consultant can request or use that are simple to generate and that could be of use. Drawings that can be generated with a few mouse clicks would include exact take-offs, three-dimensional renderings, and three-dimensional cross sections of the building.

CONSULTANTS

The cost to be on the cutting edge can be prohibitive, with little to gain in the near term. But be aware it is out there and that architects, engineers, contractors, and building owners alike may begin to ask consultants to provide BIM content. It may be five to ten years before this becomes mainstream. Currently, two-dimensional content such as roof plans and details are typically incorporated into the BIM file and become part of the "database." They remain as a separate drawing or sheet, but travel with the BIM file.

In the Madison office of SRI, a construction project has been ongoing for six years and is now in Phase 3 of construction. Phase 1 was a completely two-dimensional product – big rolls of plans, if you will. But Phase 2 and 3 have been done in BIM. SRI has used the BIM models to show 3-D renderings to waterproofers and discuss construction phasing of the roofing. However, any design documents SRI is providing are still two-dimensional content. BIM software just isn't able to do detailing yet like good old two-dimensional drawings.

So in the short-term, consultants need to ask and be aware of BIM usage on new construction. There are many ways to use it to one's advantage, and they are just a few clicks of the mouse away. For future use, begin to look at BIM now. There are numerous blogs, chat rooms, and video tutorials about BIM that expand on what is covered in this article and provide some how-to training. Software resellers have what they call "BIM Boot Camp," a five-day class for CAD-capable people to teach the basics of BIM packages and BIM modeling.

MANUFACTURERS

Roofing manufacturers are in a slightly different boat here, in my opinion. Many architectural firms rely on their standard details for day-to-day designs, only calling in roof consultants on the very difficult pro-

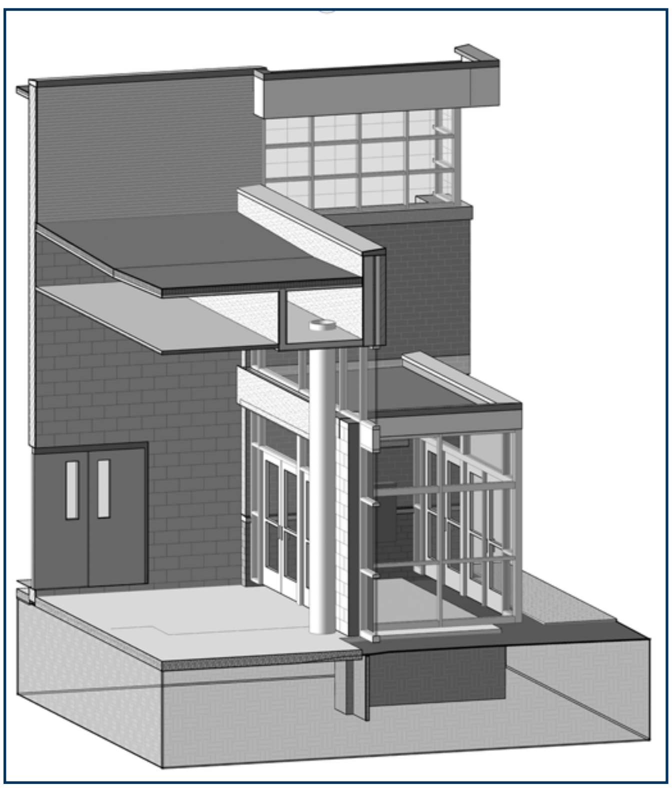


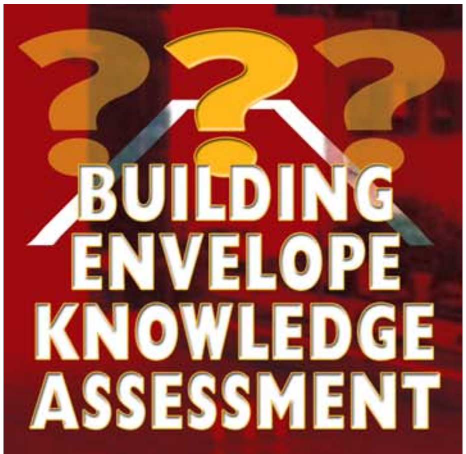
Figure 8 – This is a close-up view of detail A7 on the architectural sheet in Figure 6. Courtesy of Eppstein Uhen Architects, Milwaukee, WI.

BUILDING ENVELOPE KNOWLEDGE ASSESSMENT

Test your knowledge of building envelope consulting with the following questions developed by Donald E. Bush, Sr., RRC, FRCI, PE, chairman of RCI's RRC Examination Development Subcommittee.

1. **What is a bearing wall?**
2. **What is a bonded wall?**
3. **What is a composite wall?**
4. **What is a panel wall?**
5. **What is a masonry bonded hollow wall?**
6. **What is a solid masonry wall?**
7. **What is a bond beam?**

Answers on page 14



Answers to questions from page 13:

1. **A wall supporting a vertical load in addition to its own weight.**
2. **A masonry wall in which two or more wythes are bonded to act as a structural unit.**
3. **A multiwythe wall in which at least one of the wythes is dissimilar to the other wythe or wythes with respect to type of masonry unit.**
4. **An exterior nonload-bearing wall wholly supported at each story.**
5. **A wall with internal air space, the spacing and backing wythes of which are connected with masonry headers.**
6. **A wall built of solid masonry units, laid contiguously, or with the collar joint between the units filled with mortar or grout.**
7. **A course or courses of a masonry wall grouted and usually reinforced in the horizontal direction serving as an integral beam in the wall.**

REFERENCE:
Masonry Design and Detailing **(Fourth Edition) by Christine Beall**

jects. But politics and personal relationships aside, if Manufacturer A has all its boilerplate specs and details in a BIM-friendly format, and Manufacturer B does not, and the architect's firm designs exclusively in BIM, which is easier for him to use and which will he prefer? The current buzzwords of green, cool, and photovoltaic aside, the easier road for the architect is to drag and drop content from a Web site rather than redraw it from a PDF or outdated DWG file.

SRI has had discussions with one manufacturer about its efforts to develop BIM content. It has not been easy, due to the aforementioned fact that BIM packages aren't really capable of doing things like roofing details. However, roofing and waterproofing accessories could be done at this point; for example, roof hatches could be modeled for download and insertion into a BIM model.

BIM may not be necessary for consultants at this point or even in the budget. But the highly competitive nature of manufacturing may push this issue faster than others.

CONCLUSION

There is a lot of information crammed into this article. If readers take away just an idea of what BIM is and what it can do, the goal has been met. Each of us, as professionals, needs to pursue BIM and its future differently in our various markets with our diverse clients. But as the building envelope industry, we need to embrace this change, not resist it. BIM is coming; it really is just a question of how fast.

REFERENCES

1. Teicholz, Paul, 2004, AECbytes Viewpoint #4, www.aecbytes.com /viewpoint/2004/issue_4.html.

Mathew Dupuis

Mathew Dupuis is a second-generation engineer and has been with SRI Consultants for almost 10 years. He currently oversees a variety of forensic investigation and design projects for SRI. His area of specialization lies in roofing and waterproofing systems and their related structural assessments, moisture problems, and corrosion issues. He has worked nationwide on projects ranging from residential to commercial projects valued in the billions of dollars. Dupuis is fluent in the use of RAM for structural finite element modeling, WUFI for finite element analysis programming for thermal and moisture movement in materials, and the Autodesk Revit family of Building Information Modeling (BIM) platforms. He is a certified (Level 1) thermographer through the FLIR Infrared Training Center. Matt earned his bachelor's and master's degrees in civil engineering from the University of Wisconsin at Madison. He currently is a doctoral candidate in the Civil Engineering Department at UW Madison with a research focus on adhesion mechanics of asphalt roofing products. In addition to doing his doctoral research, Dupuis also instructs the Civil Engineering Department's course on Building Information Modeling (BIM).

Canadian Cities Requiring Green Roofs

The city of Toronto has followed the lead of two British Columbia municipalities, Port Coquitlam and Richmond, in passing new green roof bylaws (ordinances) for all classes of new buildings permitted after January 31, 2010 (industrial buildings after January 31, 2011).

Toronto's bylaw requires a green roof on any new construction with a gross floor area of over 2,000 sq m (about 21,500 sq ft). Green coverage will vary between 20% and 60% of the roof area, except with industrial buildings, which must cover 10% of available roof space up to 2,000 sq m.

Developers have balked at the proposed bylaw, noting vegetated roofs could cost \$10 to \$40 per sq ft more to install than conventional roofs.

— Roofing BC, Living Architectural Monitor