14TH CANADIAN MASONRY SYMPOSIUM
MONTREAL, CANADA
MAY 16TH – MAY 20TH, 2021

THE ENVIRONMENTAL BENEFITS OF USING MASONRY-SPECIFIC BUILDING INFORMATION MODELING SOFTWARE

Biggs, David[1]; Cuneio, Thomas[2] and Swanson, Mark[3]

ABSTRACT

In 2011, the masonry industry in the United States and representatives in Canada united to create the Building Information Modeling for Masonry Initiative (BIM-M). BIM-M set out to identify barriers to and develop strategies for the full implementation of masonry materials and systems into BIM software for the design and construction industries. The mission chosen was to unify the masonry industry through the development and implementation of BIM for masonry software to facilitate smoother workflows and collaboration across all disciplines from owners, designers, manufacturers, masons, contractors, and construction managers.

One major success of the BIM-M Initiative has been the establishment of a masonry-specific BIM software, *Masonry iQ*. This software was developed by a third-party vendor to meet the requests of the BIM-M Initiative for masonry functionality to serve the industry's design and construction needs.

While BIM-M was initially intended to improve design and construction workflows and efficiency, we are now recognizing the opportunities for improving environmental and working conditions from using BIM software with masonry projects. This paper will discuss how programs like *Masonry iQ* improve sustainability and reduce material waste, noise, and dust at the manufacturing and construction sites; lessen the demands on our infrastructure and transportation systems; and overall mitigate the effects of construction activities on our environment.

KEYWORDS: *BIM-M, building information modeling, environmental, masonry, Masonry iQ, sustainability*

[1] Principal, Biggs Consulting Engineering, 26F Congress St #305, Saratoga Springs, NY, 12866, USA, biggsconsulting@att.net
[2] President, 3DiQ Inc., 18336 Edison Ave, Chesterfield, MO, 63005, USA, tom@3diqinc.com
[3] North Central Regional Director, International Masonry Institute, 312 Central Ave SE Minneapolis, MN 55414, USA, mswanson@imiweb.org

INTRODUCTION

BIM

Building information modeling (BIM) can be described as the process of generating, implementing, and managing digital information in the design and construction process. Many international organizations have adopted specific definitions. One such definition from ISO (International Organization for Standardization) [1] defines BIM as: "Use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions."

The National BIM standard in the United States [2] considers BIM as three distinct but interconnected functions, Building Information Modeling, Building Information Model, and Building Information Management.

- Building Information Modeling is "a business process for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms."
- Building Information Model is "the digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards."
- Building Information Management is "the organization & control of the business process by utilizing the information in the digital prototype to affect the sharing of information over the entire lifecycle of an asset. The benefits include centralized and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as-built documentation, etc. – effectively developing an asset lifecycle process and model from conception to final retirement."

From a commercial perspective, Autodesk, one of the world leaders in developing BIM technology, states that "Building Information Modeling (BIM) is a process that begins with the creation of an intelligent 3D model and enables document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance)."[3]. This concise statement seems to embody the three functions of the BIM standard.

According to a survey of construction professionals recorded in the National BIM Report [4], Revit® and AutoCAD® account for approximately 70% of the software distributed for models and drawings in the UK (Revit® 50%; AutoCAD® 20%). Autodesk reports those numbers are similar in the United States.

The term BIM arose around the year 2000 with early development work having begun in the 1980s [5]. By every metric, BIM continues to grow worldwide as the acceptance rate increases. The National BIM Report 2020 [4] noted that between 2010 and 2020, BIM had gone from limited awareness by professionals to almost universal awareness. UK usage has gone from 13% in 2011 to 73% in 2020.

There are several drivers of BIM technology. The BIM report states "It (BIM) has required substantial change to workflows but has brought benefits: improved coordination of information, reduced risk, improved productivity, greater efficiency, and operation and maintenance savings. These improvements are helping to create a more efficient, transparent industry that makes fewer mistakes." These benefits appear to be universal.

Despite the benefits, there is still reluctance among small users to adopting BIM. The cause for the reluctance is often cited as the cost to implement, lack of client requirement, projects too small, and not suited to refurbishment projects. Repeat users are more likely to say the benefits are there for every project.

Many governments have acknowledged the benefits of BIM and either have or are moving toward BIM mandates for their projects. Currently, 27 countries fit that category. Progress seems slow but considering it has only been about 10 years in use, BIM is spreading quite quickly. Professionals working internationally are a major factor in that spread. In the UK for new construction, professionals report 62% usage on private projects and 57% on public projects. The government numbers are lagging but increasing.

The benefits of BIM are clear. Professionals have been seeking these benefits for decades and that will continue forever. It all starts with improving the coordination of information; in this case, building information. Better coordination leads to less wasted effort and greater efficiency in both design and construction. Greater efficiency then results in better productivity.

BIM is not just alluring because it could result in faster and cheaper design and construction. It must be valued for its ability to result in producing safer designs which thereby reduces the risk to the design professionals, the constructors, the operators of the buildings, and ultimately the users.

The essence of BIM is the digital model that is the depository of the information. However, it's important to note that the building information model is not just a design and construction tool; it can live long after construction since it holds the data to maintain and operate the building. Many operators of large facilities have learned the benefits of maintaining the model and updating it. This is still a largely untapped resource for BIM for smaller operators or owners of one-off builds.

BIM-M

Building Information Modeling for Masonry (BIM-M) Initiative is a response to and an outgrowth of BIM in the United States. Begun in 2011, the initiative was formed with the leadership and financial support of the International Union of Bricklayers and Allied Craftworkers (IUBAC), the Mason Contractors Association of America (MCAA), the International Masonry Institute (IMI), the National Concrete Masonry Association (NCMA), the Western States Clay Products Association (WSCPA) and The Masonry Society (TMS). Nearly 40 additional organizations joined the initiative as sponsors and transformed the initiative to also include factions from Canada. The initiative adopted a mission, "To unify the masonry industry and all supporting industries through the development and implementation of BIM for masonry software to facilitate smoother workflows and collaboration across all disciplines from the owner, architect, engineer, manufacturer, mason, contractor, construction manager, and maintenance professionals."

Previously, the masonry industry had no BIM effort and was dependent upon software vendors for whatever advancements were coming. That was deemed untenable and a bold effort was undertaken through the BIM-M initiative to fulfill the stated mission. Other industries structural steel, concrete, wood, etc. had already begun BIM efforts or were planning to do so.

The BIM-M initiative advocates for innovative software solutions that reduce environmental impacts and provide designers and contractors better tools for designing and constructing masonry projects. The initiative's first symposium was held in 2012 led by the Digital Building Laboratory of Georgia Institute of Technology to gather stakeholder input toward the development of a BIM-enabled masonry industry. Stakeholder input was essential.

BIM-M has now completed numerous projects [6]. Some of these include a) the MUD (Masonry Unit Database). This free database (MUDB.org) is the first-ever resource for digital representation of generic masonry available via a website or a plugin for Revit® units that enables users to download various 3D masonry units into multiple software platforms. b) LOD (Levels of Development) "is a reference tool intended to improve the quality of communication among users of Building Information Models (BIMs) about the characteristics of elements in models." LOD enables the AEC (architecture-engineering-construction) industry to specify and articulate with a high level of clarity the content of building information models; the higher the LOD number, the greater the detail and information. Masonry LOD was first introduced with the 2014 Level of Development Specification by the BIM Forum and is updated yearly [7]. c) Masonry Content Pack is a free, generic masonry content library for use with the Revit® software. Bond beams, vertical grouted cells, rebar reinforcement placement can be accomplished with this tool. The tool is effective for use in quantification, virtual mockups, and clash detection. While the content is updated yearly, the delivery systems of technology are always changing. The pack is currently being updated to a new technology platform called HIVE, a cloud-based content management system, a central, single-source database. Working with an outside developer, BIM-M along with the International Masonry Institute will have a public library of quality masonry content that is usable, and searchable. This platform is scheduled to go public by the 3rd quarter of 2021.

Another major success from the BIM-M Initiative has been the development of *Masonry iQ*. This masonry-specific Revit® plug-in was developed by 3DiQ Inc. to meet the requests of the BIM-M Initiative for masonry functionality to serve the industry's design and construction needs. *Masonry iQ* allows architects to improve their workflow while creating 3D models with masonry-specific wall types, stock or custom bond patterns, and computer analysis of wall geometry that includes corner bonding. Users can browse the materials from the MUD and select masonry producers, place their choices directly into the design, and have the software do all the calculations as well as render the units accurately. Drawing production is greatly enhanced and continuity of details is assured.

The transformative software has appealed to masons as well; so much so that "*Masonry iQ Build*" is coming specifically for masons and due for release in 2021. Besides all the features of *Masonry iQ*, "Build" will also emphasize reinforcement placement and estimating. Figure 1 shows a graphic of the reinforcement detailing. Figure 2 shows the possibility of bond and unit layout. Every unit will be identified in the model and the estimate will quantify all units for costing. These features and more will make this a major tool for masons.

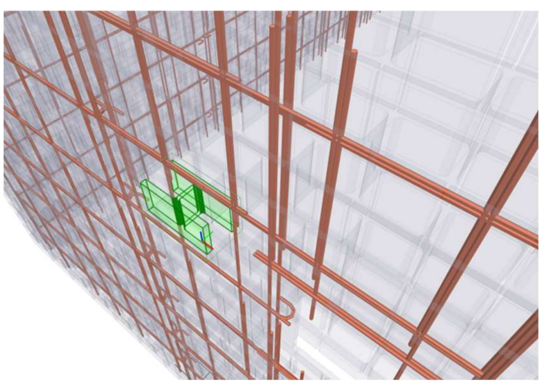

Figure 1 – Reinforcement Detailing

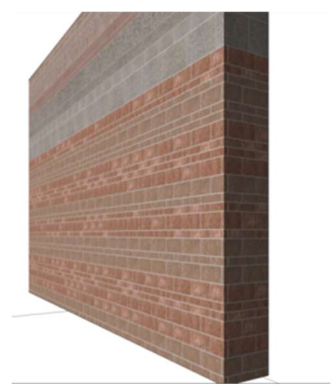

Figure 2 – Bond Layout

ENVIRONMENTAL BENEFITS

General

While BIM-M was primarily intended to improve design and construction workflows and efficiency, expanded opportunities for improving environmental and working conditions by using BIM software with masonry projects have emerged. Designers often think of using BIM for saving their design time and money, making construction more efficient, and maximizing the efficient use of materials. While these are extremely valid concerns, the conversation should also include the environmental benefits which are real but not often spoken.

Using masonry-specific BIM programs like *Masonry iQ* will improve sustainability and reduce material waste, noise, and dust at the manufacturing and construction sites; lessen the demands on our infrastructure and transportation systems; and overall mitigate the effects on our environment. In these days of rating projects using such systems as LEED (Leadership in Energy and Environmental Design), the U.S. Green Building Council [8] states that LEED "is the most widely used green building rating system in the world. Available for virtually all building types, LEED provides a framework for healthy, highly efficient, and cost-saving green buildings. LEED certification is a globally recognized symbol of sustainability achievement and leadership." In these ratings, why not include BIM software usage as a mandate for all the environmental benefits derived?

Sustainability

Research in India [9] has stated that "the construction sector in India accounts for nearly 24% of the total direct and indirect emissions of CO_2 [in India], and is the highest consumer of natural resources and energy in comparison to other sectors." These percentages may vary from country to country, but it is a fact that construction and building operations are the major consumers of energy.

According to the International Energy Association (IEA) "The buildings and buildings construction sectors combined are responsible for over one-third of global final energy consumption and nearly 40% of total direct and indirect CO_2 emissions. Energy demand from buildings and buildings construction continues to rise, driven by improved access to energy in developing countries, greater ownership and use of energy-consuming devices, and rapid growth in global buildings floor area"[10]. As the IEA notes, energy demand continues to rise. Therefore effort toward greater sustainability is essential. By making designs more efficient so that the use of materials is optimized, masonry-BIM software can be a tool for driving down energy consumption by the masonry industry.

The European Union indicated that "Construction and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the EU. It accounts for approximately 25% - 30% of all waste generated in the EU and consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos, and excavated soil, many of which can be recycled." [11].Changing that percentage by even 5% can have a large economic and environmental impact. In 2018, The EU embarked on a program (Construction and Demolition Waste Protocol and Guidelines) to stem the growth of waste into landfills.

BIM offers improvements for all aspects of sustainability.

Reduce Waste Through Design

When discussing efficient design, designers think of the time to create a design. Figure 3 shows a model that was produced in 36 minutes with over 100,000 masonry units. This level of detail and speed was never possible before BIM. Unit colors, textures, sizes, quantities, and properties are now all available at a fingertip.

Not only can designs be developed quicker, but they can also be more efficient by eliminating cuts and broken units by producing designs using the modularity of the units. Using BIM models to better coordinate masonry layouts, dimensioning, coursing, reinforcement, and bonding patterns can minimize site problems, rework, and waste.

One only needs to visit a masonry construction site to observe the piles of cut and broken units. Breakage is an unfortunate result of manufacturing and handling. However, cut units are the misfortune of design and layout. BIM software, particularly *Masonry iQ*, made modular layout a priority to improve aesthetics and minimize the need for cuts or partial units. Figure 4 shows a corner where the software discovered a break in modularity that would normally require cutting. The designer can see this and modify the building dimensions to eliminate them. Previously, this would often be left to the mason to cut the units. Fewer cuts mean less waste, fewer resources to fabricate the units initially, and lower carbon emissions.

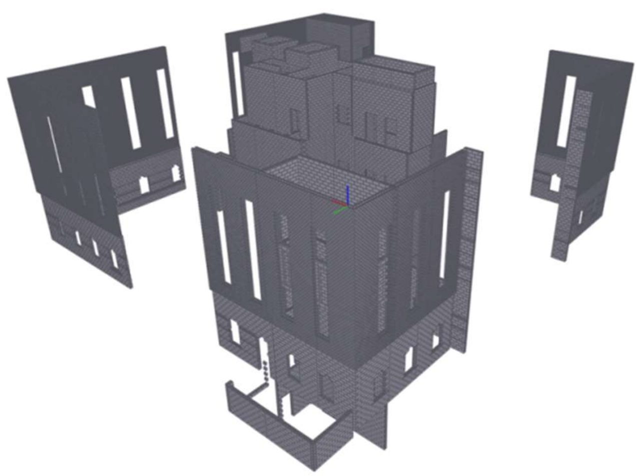

Figure 3 – Model with over 100,000 units

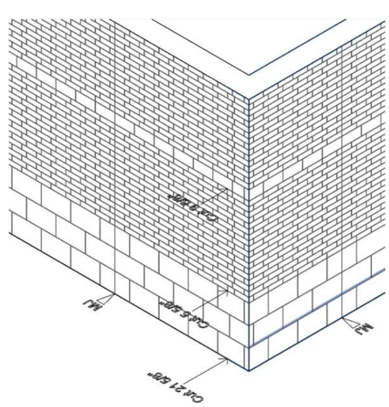

Figure 4 – Corner modularity

Reducing Waste During Construction

Mock-ups are the proving ground for project details. But, they require extra materials, work, and waste. BIM offers virtual mockups and cloud-based documentation for potential savings. Essentially, you build it virtually before the actual construction is performed utilizing a BIM process where access to the latest drawing revisions by way of a cloud-based management system can update entire project teams quickly.

Excess material stored onsite or stored in a yard creates inventory waste and many times winds up in landfills or has to be transported offsite to recycling facilities. Using tools for modular dimensioning and coursing of masonry walls can reduce the amount of initial material ordered. Optimizing just-in-time inventory with accurate quantity counts from BIM models can reduce this waste.

Reduce Noise and Dust

Whether cutting units is done at a manufacturing site or the building site, eliminating cutting has so many benefits. We previously noted the reduction of waste. However, that reduction has additional reductions of noise, worker time, dust, the requirement for personal protective equipment, clean up, and tool consumption.

Lessen demands on infrastructure

Construction activities have a major impact on our infrastructure. This includes such aspects as energy, water, lighting, roads, waste management, and recycling. Each is impacted and has a real or societal cost.

The reduction in energy costs and water usage can be quantified by each masonry manufacturing facility based upon units manufactured. Less waste would mean less material to be fabricated and fewer raw materials required.

While transportation of materials is necessary for building buildings, the unnecessary movement of materials or equipment can be reduced by better planning with BIM tools. Using the BIM-M software tools, transportation can be minimized by better communication and coordination reducing counterproductive uses of energy and limiting masonry material handling damage.

CASE STUDIES

Obtaining exact data of BIM effects on the environment is still in the opportunistic phase, the following case studies highlight the potential of masonry-BIM software to mitigate detrimental environmental issues.

Case Study 1:

This case study is based upon experience by one of the authors over the past 17 years using 3D-CAD and BIM software as a service provider (CADBlox and 3DiQ). The service identifies every masonry unit on each project. For each project, the design was checked and modifications were proposed to the project architect. Many were accepted to make the masonry wall designs more economical and efficient; others were built as designed.

- For over 50% of the projects, the design included cut units due to problems with modular coursing and opening layout.
- In 2020, the service provided details for over 6 million masonry units (concrete and clay). Of that total, the number of cut units exceeded 300,000 for an estimated 5% cut units.
- The National Concrete Masonry Association estimates about 1.2 billion units were manufactured in the United States in 2020. The Canadian Concrete Masonry Producers Association estimates Canadian 2020 production was 40 million units.
- Applying the 5% estimate, that would mean approximately 62 million units were cut in 2020 in the US and Canada.
- Assuming a standard 200-mm (8-inch) CMU:
  - a cut is 5 mm (3/16" wide) through the two face shells of a concrete masonry unit (CMU); each face shell is 25 mm (1 inch) thick
  - a unit cut produces 49,161 mm^3 (3.0 in^3) of pulverized masonry.
- For the US and Canada, that translates to 3,048 m^3 (107,639 ft^3) of dust.
- Using an average unit weight of the CMU of 842 kg/m^3 (115 pcf) amounts to 2,566 tonnes (6,189 US tons) of dust that need not go into the atmosphere or a landfill.

These numbers are only an estimate but they do indicate the relative magnitude of the issue.

Case Study 2:

This study represents one specific retail building. Figure 6 shows a 534 m^2 (5,753 ft^2) retail building comprised of 11,418 architectural, single-leaf CMU walls. The approximate surface area of the masonry on the walls is 645 m^2 (6,940 ft^2). All data was derived from the model.

Figure 6 – Retail building

The architectural design was advanced without the use of masonry-BIM software and constructed without a BIM construction process. As a retrospective, the design model was analyzed by *Masonry iQ* which revealed that 396 cut units (3.5% of the total) were required to implement the original design. Site photography revealed that all of these unnecessary cuts were performed representing a typical scenario in construction that is not BIM-enabled. Through slight dimensional changes to the exterior, those cuts could have been eliminated resulting in:

- improved aesthetics
- noise reduction
- a reduction of 35.8 kg (79 pounds) of dust that would have been released into the air or collected and added to the waste stream.
- a labor savings of approximately $2,700 (USD) by eliminating the cutting.
- added savings of less labor for material clean-up, waste removal, and transportation to the waste site.
- environmental savings by way of reduced CO_2 emissions, reduced dust into the air, less transportation to both the building site and the waste site, reduced fuel usage, and less wear and tear on the roads.

The lessons learned are being used to improve future designs by the architect.

***Case Study 3*:**
This project was a hospital addition (Figure 7) that consisted of over 45,000 modular brick and almost 30,000 CMU [12]. The site was extremely congested and storage space was limited. The mason contractor created a BIM model using individual units and used it for material quantities and approval of the layout before ordering. The original architectural model was created using software that did not adjust for modularity. The contractor was able to create RFIs and adjust for modularity. These layout issues were resolved and reduced the number of cuts and CMU block waste on the project. Environmentally, reducing cuts minimized airborne silica dust creating a healthier job site and surrounding area.

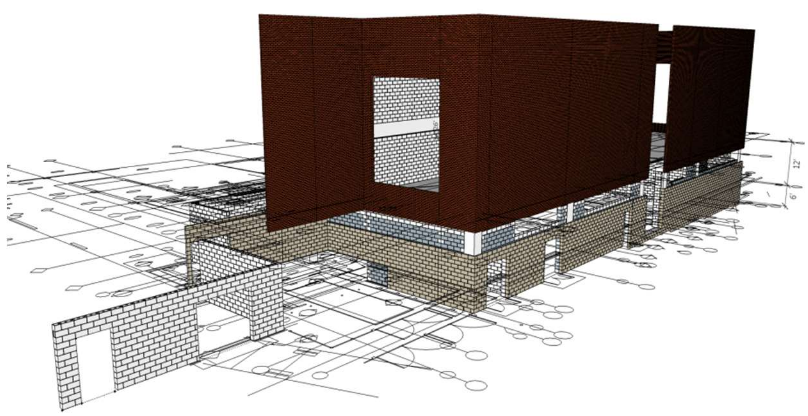

Figure 7 – Hospital Addition

SUMMARY
This paper was intended to encourage thoughts concerning the beneficial environmental effects that could be derived by using masonry-specific BIM software. The overall concept has been discussed for years [13]. However, evolving software development brings the concept into reality.

Looking at any project in isolation, the environmental benefits seem minimal. However, as an industry, the cumulative environmental effects in the US and Canada are tremendous; imagine the effects worldwide. This topic needs continued study to confirm the assumptions and quantify the environmental effects on transportation and infrastructure systems.

REFERENCES

[1] ISO 19650-1 (2018), *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) —Information management using building information modelling — Part 1: Concepts and principles,* International Organization of Standards, Geneva, Switzerland.

[2] *National BIM Standard-United States ® Version 3* (2015), National Institute of Building Sciences buildingSMART alliance®, Washington, D.C., USA

[3] Autodesk, *What Are the Benefits of BIM*, https://www.autodesk.com/solutions/bim/benefits-of-bim

[4] *The National BIM Report 2020*, The NBS, Newcastle upon Tyne, UK (2020)

[5] Gentry, T. R., Eastman, C., and Biggs, D. T. (2013). "Developing a roadmap for BIM in masonry: a national initiative in the United States." *Proc., 12th Canadian Masonry Symposium*, Vancouver, BC, Canada.

[6] Building Information Modeling for Masonry (BIM-M), https://www.masoncontractors.org/bim/#newsletter

[7] Level of Development Specification For Building Information Models (2014), BIM Forum, https://bimforum.org/lod/

[8] *Value of LEED,* U.S. Green Building Council, https://www.usgbc.org/leed/why-leed

[9] Ritu Ahuja, R., Sawhney, A. and Arif, M. (2017), "Driving lean and green project outcomes using BIM: A qualitative comparative analysis" International Journal of Sustainable Built Environment, http://dx.doi.org/10.1016/j.ijsbe.2016.10.006

[10] *Energy Technology Perspectives 2020,* International Energy Association, www.iea.org

[11] Construction and Demolition Waste (2019), European Commission – Environment, Waste, Waste Streams, https://ec.europa.eu/environment/waste/index.htm

[12] *#6, Case Study,* "BIM Deliverables Guide for Masonry Contractors Volume II Building Information Modeling for Masonry" (2016), https://www.masoncontractors.org/pdf/bim-deliverables-guide-for-masonry-contractors-vol-ii.pdf

[13] Liu, Z.; Osmani, Mohamed; Demian, Peter; Baldwin, Andrew N. (2011), "The potential use of BIM to aid construction waste minimalisation." Proceedings of the CIB W78-W102 2011: International Conference. 26th-28th October 2011, Sophia Antipolis, France, paper 53.