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**THE BENEFITS OF USING BUILDING INFORMATION MODELING
IN STRUCTURAL ENGINEERING**

by

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A report submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

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2013

ABSTRACT

This paper explores how the use of Building Information Modeling (BIM) can be a beneficial platform for structural engineers. The current state of BIM is analyzed, giving a general overview on how architectural; engineering and construction firms are applying it on their projects. The applicability of BIM to structural engineering is discussed, and how it impacts the structural design and its workflow. The benefits of using BIM in structural engineering are then analyzed, in the areas of productivity, coordination, and visualization, and a case study is developed to test the interoperability between BIM software and structural analysis software. The findings of this study provide useful information for everyone interested in increasing their knowledge on BIM technology in structural engineering.

(42 pages)

ACKNOWLEDGMENTS

I would like to thank everyone that in one way or the other made this project possible. I would like to thank my advisor and major professor, Dr. Marvin Halling for giving me the opportunity to do research and for guiding me through the culmination of my master's degree. I am thankful for the members of my committee, Dr. Paul Barr and Dr. James Bay for their support and guidance on this project.

Thanks to my family, especially my parents, Cesar and Janet, for their unconditional love and continuous support even throughout the distance. There is no doubt that I would not be the man I am today if it was not because of them.

I would like to thank all the wonderful friends that I have made here at Utah State University. All of them, especially Marcelle, Rafael and Wilhem, have been an incredible support these last couple years, and they have earned a good spot in my heart.

Cesar Hunt

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CHAPTER I

INTRODUCTION

The use of new methods and software is one of the most important tools that structural engineers are using nowadays to stay competitive (Autodesk, 2012). Engineers are constantly looking for new ways to improve and keep the pace on today's economy, meeting critical points in work like productivity, coordination and problem solving. Building information modeling (BIM) can potentially help with these important aspects. The core feature that BIM offers is the ability to integrate intelligent objects in the model. These intelligent objects contain all the data regarding a specific component, from geometric characteristics to the way they interact with other components, making the entire model full of information.

The use of models is not a new trend. Big companies like Toyota have been using them for quite some time to support their manufactory and complex engineering processes, especially in the design and documentation phase (Autodesk, 2011). Applying this same principle to infrastructures and building projects in the architecture, engineering and construction industry is what has developed in what we know as BIM.

The environment that BIM adoption is creating is similar to when other technologies, like computer aided design (CAD), were adopted in the industry in the past 50 years. (McCuen, Suermann, & Krogulecki, 2012). The fact that architects and designers switched their methodology and started using 2D CAD changed the way we work, and BIM has the potential to do the same. Many consider BIM to be an evolution

of CAD based technology and believe it will result in great benefits for the architecture, engineering and construction industry. (Migilinskas, Popov, Juocevicius & Ustinovichius, 2013).

Structural engineers can take advantage of BIM in different ways, as the model can be constantly updated with any changes in the design or general specifications, keeping all the data as accurate as possible (Azhar, 2011). Some of the most important contributions of BIM for structural engineering activities, like conceptual design, structural analysis layout and detailing are: reduction of design and drafting errors and reduction of direct engineering design and drafting costs as a result of improved productivity. It also allows for better analysis of situations through simulation. The fact that the use of BIM lets one visualize the whole picture lets one identify potential design issues, and come up with new and creative ways to solve problems.

This paper will focus on the state of building information modeling and its influence in structural engineering. The benefits that BIM represents for structural engineering in the areas of productivity, coordination and consistency of data, and visualization and simulation are also investigated, all this with the objective of obtaining a clear idea of the impact that BIM has in structural engineering.

CHAPTER II

LITERATURE REVIEW

BUILDING INFORMATION MODELING

Building Information Modeling (BIM) is a methodology of design that is based on data rich objects that form a model that is used in architecture, engineering and construction. Part of the central point of BIM is the fact that all the objects that are part of it have their database that can interrelate to other objects within the model (Ikerd, 2008). The National BIM Standard (NBIMS) defines BIM as “a 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 onward. The BIM is a shared digital representation founded on open standards for interoperability.”

The results of extensive research and development in academia and industry have brought many powerful and practical building information modeling tools for analysis, design and detailing. (Migilinskas et al., 2013). Within a BIM, different disciplines can include their data, from the architect, structural and MEP. Even details such as finishes, like specific manufacturers, pricing, can be included as digital data in BIM. This information is available prior, during and after the construction. Everyone that is working on the project can access all this information, not only facilitating the process of sharing information, but maintaining the data more consistent and coordinated around the different disciplines.

To have an effective cooperation between the different engineering disciplines it is necessary to have the infrastructure's data properly organized (Shim, Yun & Sung, 2011). BIM is known for its design and documentation capabilities, allowing the storage of useful computable information that stays coordinated and consistent along all its users (Autodesk, 2012). Structural engineers currently use BIM to mainly create drawings and for coordination (Salce, 2012).

BIM is not only a fast and convenient way to show owners and stakeholders the different designs and situations regarding specific projects, but it also lets the different parts of the design team to better coordinate fabrication of different building systems, which is one of the reasons behind the speedy adoption of this method (Nawari, 2012). The transition from the design phase to the construction of a project is also more seamless in projects using BIM. (Bynum, Issa & Olbina, 2013).

The use of BIM can completely change the way infrastructure projects are developed, executed and managed (Autodesk, 2012). The beginning of BIM was too focus in architectural area, but as part of the evolution and adoption of different industries, the different BIM software are on constant evolution to address the needs of structural engineers, offering better tools that increase its use in the field. One big difference between BIM and CAD in the initial state of design is that buildings are modeled using separate components instead of drawn. BIM skips the 2D design of its cousin CAD and jumps directly into modeling the structure. As a result, drawings are of second importance and no longer the first place to look up for design information, becoming reports of design information that are created automatically from the BIM model.

The projects designed and built today have seen a considerable impact by the use of BIM (Nawari, 2012). Evidence of this tendency can be seen in figure 1. A report from a study delivered by McGraw Hill Construction about the level of BIM implementation in infrastructure in the recent years shows how use of BIM have been increasing. Out of all the participants, about 31% are using BIM on 75% or more of their projects in 2013, up from a low 7% in 2009. The numbers of participants that are not using BIM on 25% or less have seen a dramatic decrease, from 73% on 2009 to 21% in 2013. We have got to the point where imagining big complex projects developed today without using BIM is hard (Salce, 2012).

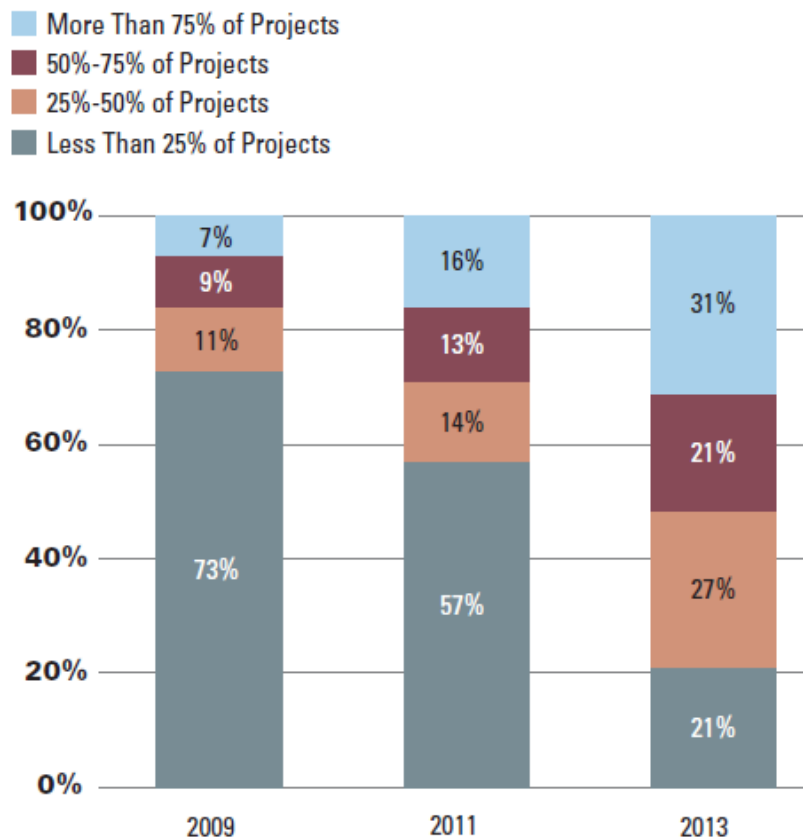


Figure 1. Level of BIM implementation for infrastructure over time. Source: McGraw Hill Construction

The improved way that the different disciplines collaborate on a project is one of the important factors behind the increasing in use of BIM in the industry (Bynum, Issa & Olbina, 2013). BIM facilitates the process of collaboration for architects, structural engineers and mechanical, electrical and plumbing professionals by allowing multiple team members to work out of the same model (Bynum, Issa & Olbina, 2013).

As can be seen in Figure 2, the user profile in the different engineering disciplines, structural engineering is in a middle ground, with more usage for infrastructure related projects than civil engineering in general. The MEP engineering disciplines, which are represented in the Other Engineers division, lead this are with approximately 60% actively using BIM in their projects.

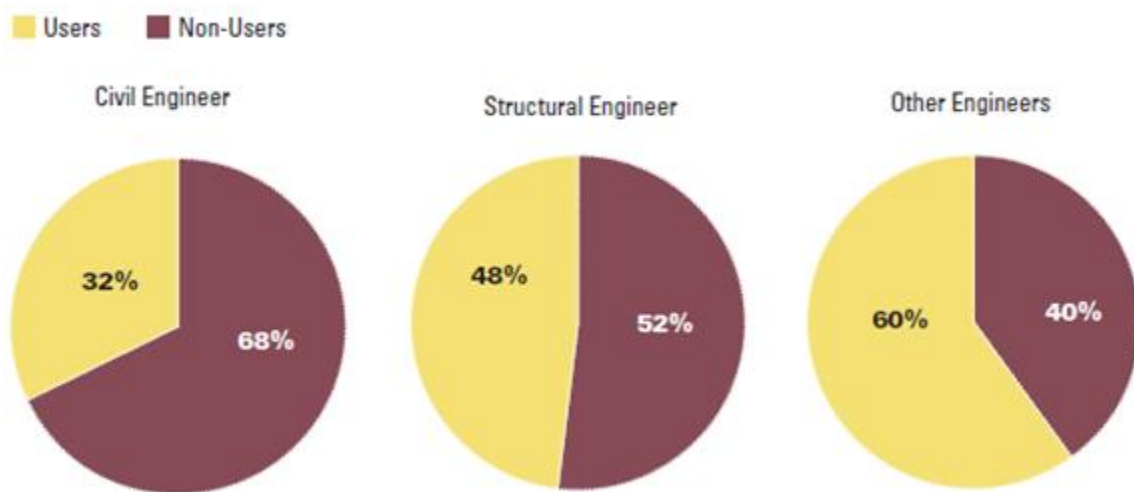


Figure 2. User profile: Engineers by discipline. Source: McGraw Hill Construction

The building information model can also contain information like structural and energy analysis, and project management and cost estimating. BIM can also include parameters like design codes and criteria (AASHTO) and other standards.

One important point behind the increase use of BIM in the industry is the fact that a lot of different disciplines can take advantage of its benefits in the same platform, including structural engineers (Salce, 2012). The complexity of many infrastructure projects requires intense multidisciplinary collaboration. (Autodesk, 2012). With BIM, project information is available and actionable throughout every phase of the infrastructure. By the start of the construction phase of a project it is possible to visualize the project through all the process of construction, including its scheduling (4D) and costs (5D) (Autodesk, 2012).

BIM IN STRUCTURAL ENGINEERING

The results of extensive research and development in academia and industry have brought many powerful and practical building information modeling tools for analysis, design and detailing. (Migilinskas et al., 2013). Developments like the affordable production of steel and commercial electrical welding machines, the personal computer and the internet have all deeply change the structural engineering profession in a number of areas like design codes, work processes and building possibilities. And analyzing the way BIM is developing, it has the potential to have even stronger impact on structural engineering (Ikerd, 2008).

There is no doubt that BIM is changing the structural engineering industry and is influencing important aspects of it (Ikerd, 2008). The structural building information modeling includes all the aspects related to the structure of a specific project (Lee, Bae & Cho, 2012).

The structural buildings that are more dependent in scheduling and prefabrication are taking a great advantage from BIM. Elements like steel and precast concrete can be coordinated more easily with BIM, improving its delivery and installation and handling, with less storage.

The process to prepare a project to input it into structural analysis software is more efficient, since all the data can be directly transferred from the building model (Sacks & Barak, 2007). The design results are stored in the building information model, becoming easily available for the detailing process.

As can be seen in figure 3, more than 50% of both the architecture and engineering firms have a very high implementation of BIM for infrastructure projects. It can also be seen that owners are closely following 42% with a high or very high implementation, and another 42% with a medium implementation. The fact that a lot of owners and stakeholders are now requesting projects to be developed using BIM is another reason behind the recent increase in adoption of BIM in the industry (Salce, 2012).

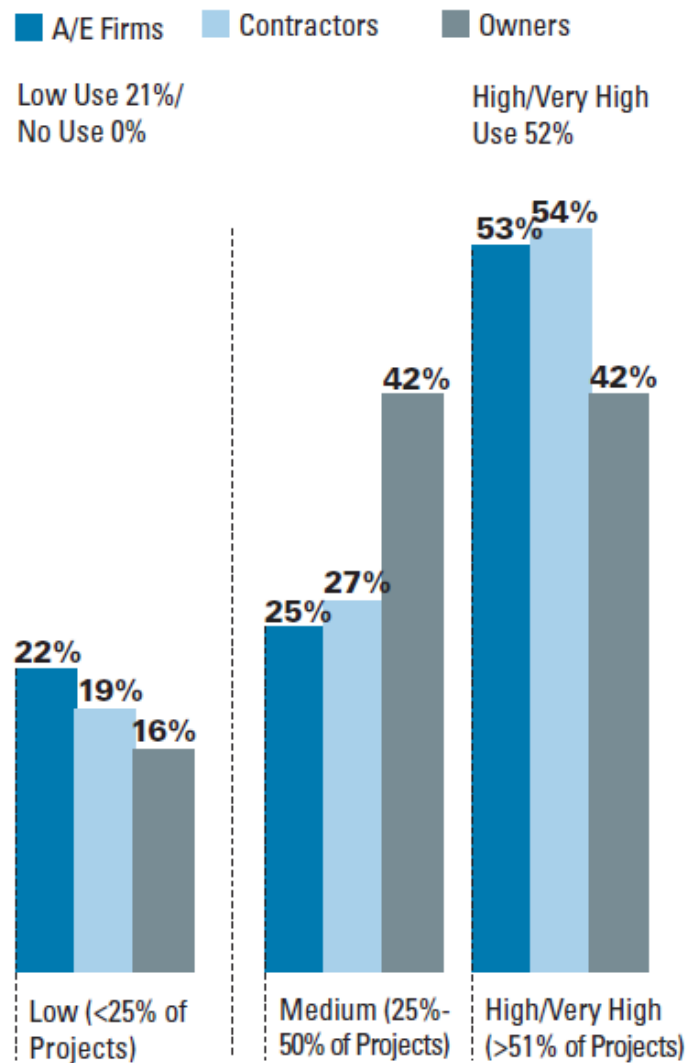


Figure 3. 2013 Implementation of BIM for Infrastructure. Source: McGraw Hill Construction

Structural Information

The types of structural information that can be included into a building information model are element type, element properties (like area, moment of inertia). Using all this information, a structural analysis model can be ready, with boundary conditions, loads, etc., that can be imported into structural analysis software.

Once the model has been updated with all the elements properties like type, material, boundary conditions, etc., the analysis for structural safety can proceed. According to the results, then the layout and construction documents can be updated with the new information.

Structural Design Process

The first step in the structural design process of a project following the traditional way is to interpret the architectural plans. This gives the structural engineer an idea of the design and set the foundation to create the analytical model that will be used in the structural engineering software to analyze the project according to the requirements, be it gravity, seismic, dynamic or wind. At the same time, usually drafters start the drawing part, creating a representation of the building and initiating the construction documents. This cause the creation of multiple drawings that contain the same information.

The fact that there are different models being worked on for the same project increases the efforts that need to be put in coordination, and opening the opportunity for errors. If there is a change that the structural engineer made to an element in the design, and that change is not updated by the drafter the documents become out of sync, affecting the validity of the design.

While using a building information model, both the physical, which contains the data used in the analysis applications, and analytical information, which is the model used in the structural analysis, are interconnected in the same place, allowing for its use not only in the structural analyses of the project, but also to produce the construction documents.

The structural members like beams, columns, that are part of the physical representation can be assigned load, material properties and other important information necessary to run the structural analysis. It also contains the geometric properties, strength of the materials, and boundary conditions of the structural members.

Structural analyses programs can then import all this information thanks to embedded tools and application programming interface (API). After the analysis process is finished, the model can be exported with the results, automatically updating all the information, and the documentation dependent from it. Analysis results such as the internal force of a structural member and the area of steel rebar can be stored into the model for future use.

This greatly reduces the time spent in detailing and drafting, since documents containing information like the geometric size of a structural member, the type and quantity of steel rebar, concrete, can be easily generated.

Structural Workflows using BIM

When compared to the traditional way to work, the benefits of using BIM in the structural design are obvious, especially when analyzing the workflow.

Time constraints usually dictate that structural design and construction documents production start parallel, so as the structural engineers begin their analyses, the structural drafters begin developing the documentation set (framing plans, bracing elevations, typical details).

The use of multiple models, models that are not coordinated with each other or the documentation, requires a manual effort to keep them and the documentation package synchronized, to the detriment of a firm's efficiency, quality, and flexibility. Whereas the use of building information model that drives analysis, coordination and documentation reduces these problems.

With BIM, referencing the architectural plans is still the first step. But instead of creating several models, there is just one model, a single integrated structural model that includes both a physical representation that drives documentation and coordination and an analytical representation used for multiples analyses.

Structural analysis

Without BIM, individual models must be produces to front end each type of analysis. One common complain of structural firms is that their highly educated staffs spend too much time transcribing information from one software package to another, configuring various analytical models for input into different analysis software applications, and then manually coordinating the analysis and design results with documentation (Autodesk, 2012).

With BIM, the analytical and physical representations are created simultaneously, and are just different views of the computable building model, containing the necessary

information needed for third party analysis applications. BIM doesn't replace the analysis applications; it provides a common modeling interface to them and a common model to document the results.

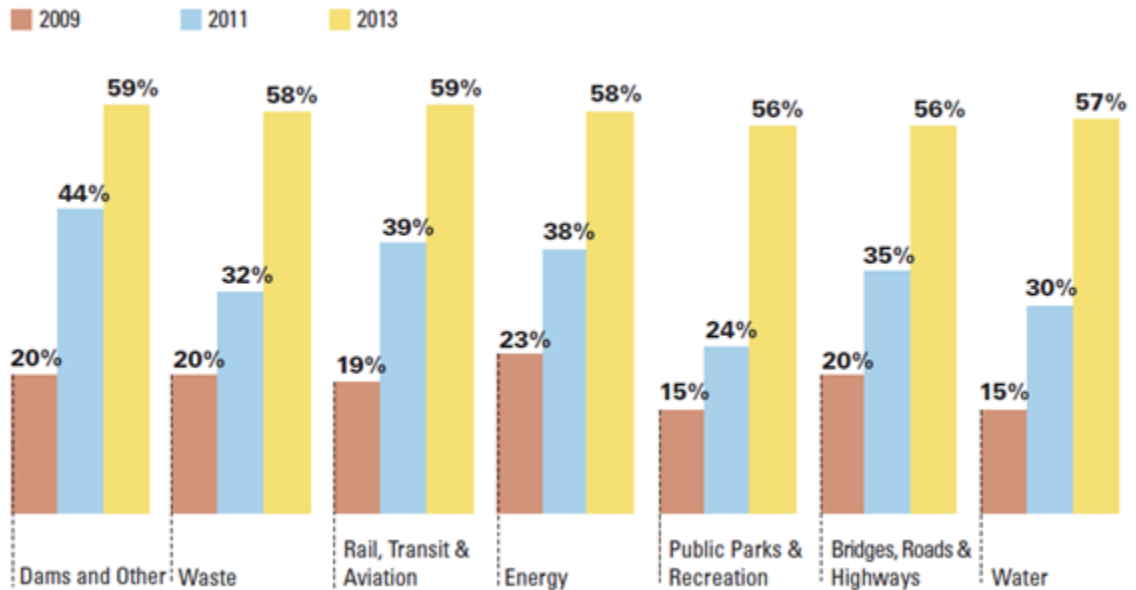


Figure 4. BIM Implementation on Infrastructure by Project Type. Source: McGraw Hill Construction

The behavior of a structure during its construction differs from its behavior during its service period, opening the possibility for dangerous situations during the first one (Zhang & Hu, 2010). Structures that vary with time require of a precise method for its structural analysis during the construction process. Using BIM, it is possible to put the time dependent actions to the model, having a 4D structural model. This is one of the main applications of BIM, since the model contains all the information, making it possible to check and avoid conflicts and safety problems (Shim, Yun & Sung, 2011).

4D structural information model

A 4D structural information model is a building information model that is complemented not only with the structural information of the project, but also takes under consideration the time, enriching all the basic information that is already part of the model (Zhang & Hu, 2010). Among the important points that are included into the new model are information like schedules, construction activities, resources, and others.

The characteristics of structures under construction are very peculiar (Zhang & Hu, 2010). Usually material properties change over time and loading conditions can vary depending on the stage and type of activities that undergo. This is why the structural analysis during constructions has a lot to do with the loading conditions, and the resistance of the elements in question.

New 3D modeling tools are allowing structural engineers and designers to create models for documentation and coordination. As a result, more and more structural engineering firms are embracing this new methodology. BIM software is based on the object oriented programming, in which instances of structural members are assembled to create a building structure. Each member possesses the information and functionality that fully defines it (a beam element has its material and sectional properties) as well as its purpose within the structure (horizontal member on X level, spanning between columns Y and Z).

The resulting BIM model contains a wealth of information which can be useful for inter discipline coordination as well as internal coordination. (Schinler, Nelson, 2008)

Structural and civil engineers are traditionally responsible for design of structural elements, highway, bridges and other infrastructure structures.

BIM based structural design tools help engineers optimize their structural design, to compare and contrast various approaches to sustainable designs with associated lifecycle costing, and when a concept is approved, it provides the foundation for construction sequencing and field operations. Fabrication and construction can be done error-free, and the effort required for checking drawing declines drastically (Uddin & Khanzode, 2012).

BENEFITS

Building information models let structural engineers design, visualize, simulate, analyze, document, and build projects more efficiently, accurately, and competitively (Autodesk, 2012). Among the most important benefits of BIM for structural engineer are productivity, coordination and consistency of data, and improved visualization and simulation of problems and situations.

Productivity

From the engineering point of view, the most important contribution from BIM is the increase in productivity, especially when producing in construction documents (Sacks & Barak, 2007). In most structural engineering firms, especially large scale ones; it is common to work with teams that are in different geographical locations. In fact, it is expected that team workers would help with different projects according to the needs of the firm in that moment.

New technologies like cloud servers make this entire process much easier. Being able to have all the information in an online hard drive, where everyone working on a project can access it and modify it does wonders when there's a significant distance between workers. When this concept is applied to BIM, and it's naturally data rich database, it greatly benefits communication and productivity (Nawari, 2012).

The production of the construction documents in 2D is the most labor intensive part of structural engineering (Sacks & Barak, 2007). This is a process that is done completely automated when using a building information model. Important sections like

reinforcement detailing, numbering and rebar schedules are automatically generated, saving a lot of time and effort. Figure 5 shows the value that architectural and engineering firms put on BIM according to the project phase. 53% of the firms that participated on the McGraw Hill Construction report list construction documentation as one of the top phases where BIM is valuable, only behind the design phase. This shows a clear indication of the benefits that the architectural and engineering firms are getting from BIM.

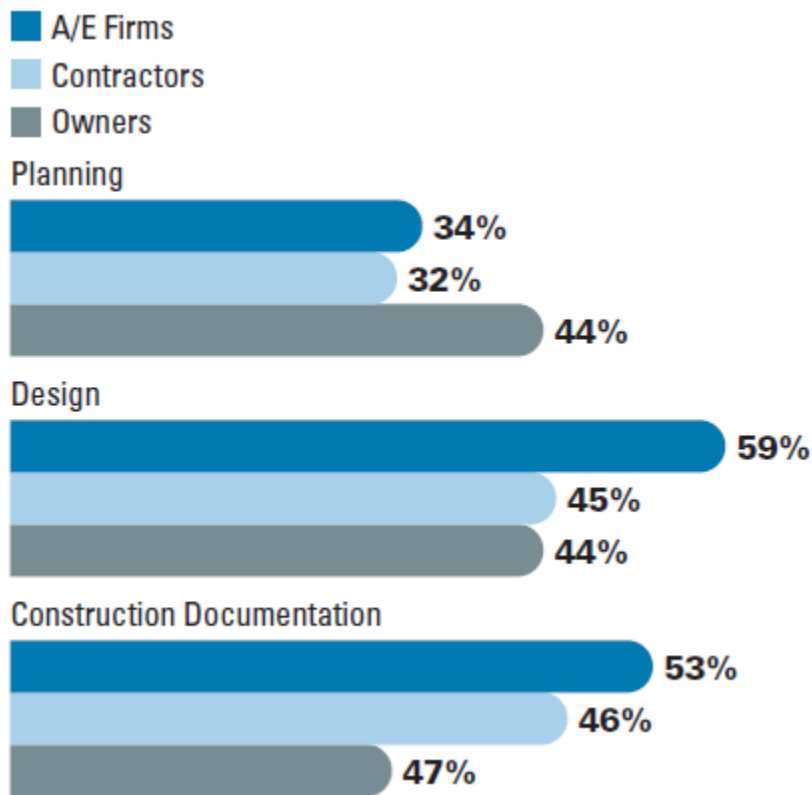


Figure 5. Value of BIM for Infrastructure by Project Phase. Source: McGraw Hill Construction

An important part of the structural design process is constantly checking the structure and be aware of needed changes in the design that require structural analysis.

Since the building information model automatically updates the entire model with significant changed information, whenever there is a change that needs to be done, engineers only have to work to change the information in one place, the model, instead of having to make sure that everyone realizes about the changes. This advantage in how easy it is to apply changes is an important productivity advantage. Errors and mistakes are common, especially when working in complex infrastructure projects where stress levels and the rush of finishing a project are present (Salce, 2012). Reducing the need to make extensive checks helps prevent errors in the documentation that can affect the construction. Figure 6 shows the top internal benefits that architectural and engineering firms are getting from using BIM for infrastructure projects. 42% of them consider the reduce errors in documents as one of the top benefits from BIM, clearly showing the improvement in using BIM at this phase of a project.

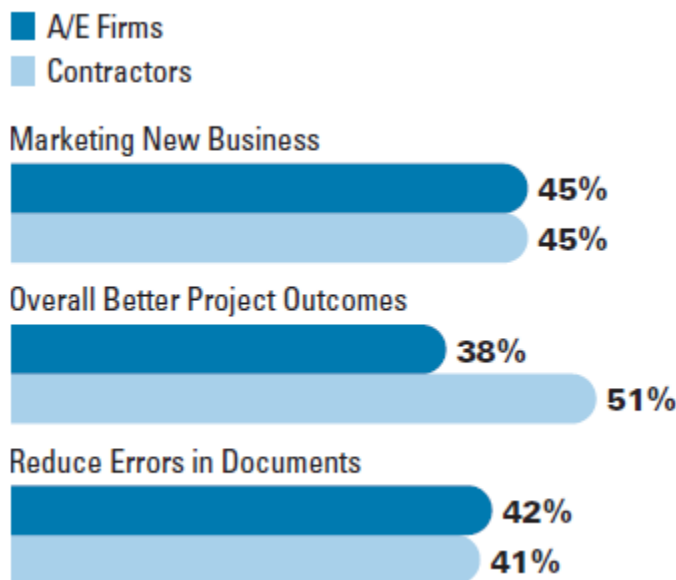


Figure 6. Top Internal Benefits of Using BIM for Infrastructure Projects. Source: McGraw Hill Construction

Coordination

Good coordination in a project is essential to get the most out of BIM (Migilinskas, Popov, Juocevicius & Ustinovichius, 2013). A single building information model is used for both the analysis and the documentation phases, contributing to better coordination between the structural analysis results and the overall design, increasing consistency throughout the entire project.

Structural engineers can easily spend more time coordinating a project than performing the structural analysis (Schinler & Nelson, 2008). With the use of BIM, the time spent in coordination is reduced, allowing structural engineers to focus all their efforts in solving problems, instead of having to constantly be checking for errors or coordinating changes made.

The documentation phase of a project is positively impacted by the use of BIM as well. Using the building information model not only enables the production of construction documents, but it also serves as a base to present the results from the structural analysis and design in an easy sharable way, keeping all the information regarding the analysis, design and documentation of a structural project in one place.

The figure 7 shows the most important infrastructure project factors that add value to BIM from the McGraw Hill Construction report. Among the top factors are project complexity and interoperability between team members' software's.

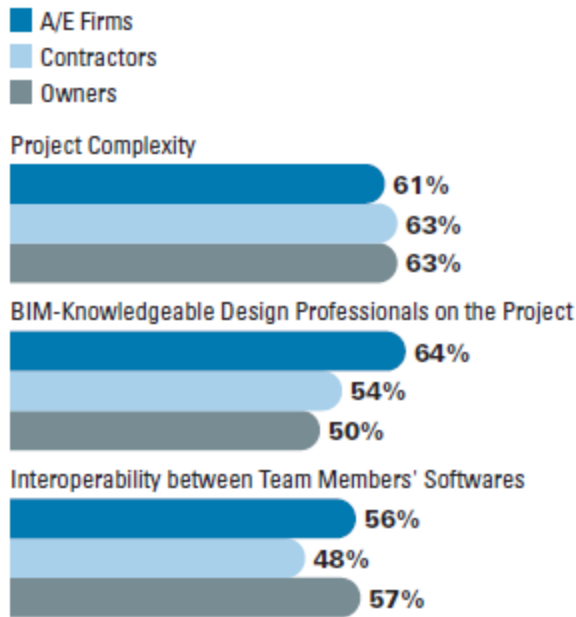


Figure 7. Most Important Infrastructure Project Factors that Add Value to BIM Use. Source: McGraw Hill Construction

The bigger and more complex a project is, the more coordination it requires. 61% of the firms that participated in the McGraw Hill Construction report agree that BIM is especially valuable when dealing with complex projects. Using BIM not only allows the team to coordinate better, but to also make better design decisions based on the model (Schinler & Nelson, 2008).

Another important factor that adds value to the use of BIM is the better interoperability between team members' soft wares. BIM offers coordination tools that let architects, structural and MEP engineers manage a project more effectively. For example, by working with the same model as a base, MEP engineers can layout their systems around the structural model, improving coordination. One of the most useful tools available is clash detection, which is a great way to reduce errors by automatically

checking for collisions or interferences between the structural system and the ducts and plumbing systems.

The coordination issues can then be identified and solved in the design phase instead of extending them to the construction, improving accuracy and reducing errors.

Figure 8 shows the number one factor that architectural and engineering firms consider to contribute to BIM benefits is the reduced conflicts and changes during construction. 55% of the firms coincide that BIM has a big impact in these factors.

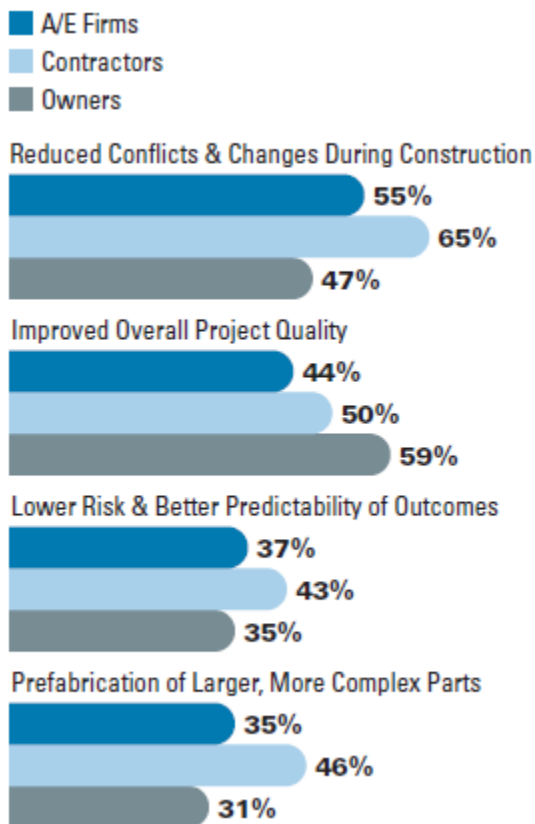


Figure 8. Most Important Benefits that Contribute Value to Infrastructure Projects.
Source: McGraw Hill Construction

BIM also ease the process of coordination when it is time to fabricate structural members. Good communication is important to make the most out of the process of modeling a structure (Amor, 2013). BIM effectively connects the structural design with fabrication, improving communication and the way information is shared between detailers, fabricators and contractors. This helps with the coordination of the production and to decrease the time needed to construct concrete and steel structures (Schinler & Nelson, 2008).

Visualization and Simulation

BIM can also be implemented to come up with new and creative solutions to problems (Bynum, Issa & Olbina, 2013). The engineers can easily isolate and filter any area or element of especial interest from the structure, and are able to visualize it in 3D. This provides great project insight, enhancing its understanding and facilitating the process of solving problems and coming up with ideas.

Optimize outcomes by exploring design alternatives more easily and cost effectively during conceptual design. Once the future design parameters are known, a BIM process can aid in the creation of alternatives that address them while helping to identify the most economical and time efficient approach to a construction.

Visualization of projects through BIM also helps improve predictability of the behavior of a structure. The analysis tools allow the evaluation of a structure performance digitally, before it is built. One of the most important benefits of BIM is the ability to create simulations and check different structural scenarios. Simulating different scenarios of a specific project greatly help with analyzing and taking decisions (Autodesk, 2012).

Some of the key attributes associated with these models will improve site planning by enabling what if scenarios to test and improve different settings (Jacobi, 2011). Simulations of installation conflicts, design clashes, and work flow management can be performed before the work begins. Construction sequences can be simulated to facilitate quick and effective decision making by the design team. Real time navigation through de modeled environment is supported during the simulations to enhance exploration. Seismic events and the possible impact that they can have on infrastructure can be simulated using BIM (Bennet, 2012).

Renders and animations can be easily generated from the building information model, simplifying the process of explaining complex situations. These visualizations can be used to present ideas in a more clear way, helping teams communicate more effectively.

BIM offers great potential in seismic retrofit and refurbishment of buildings and infrastructure projects (HM Government, 2011). Visualizations, simulations and analysis processes can help mitigate the effects of future infrastructure challenges (Bennet, 2012). Using BIM and other technologies, like laser scanning, engineers can create highly detailed structural models of different infrastructure projects that can be used for analysis. This facilitates the process of identifying and diagnosing problems that infrastructure might experience in the future, since the building information model can be easily adapted to graphically illustrate potential failures, leaks, evacuation plans, and so forth.

CHAPTER III

CASE STUDY

To understand how the connectivity of BIM software and structural analysis software works, it is important to introduce the concept of physical and analytical representation of structure (Autodesk, 2007). The physical model is a true model of the structure of a project, and the analytical model transfers all the information needed by the structural engineer. Using a building information model, both the physical and the analytical representations of the structure remain interconnected, facilitating the process of transferring information and keeping the integrity of the model.

Software Selection

The software selection is mostly determined by the structural engineering firm. Structural engineers are usually familiar with different structural analysis programs; therefore the initial selection of BIM and structural engineering software is based on the software that the engineering firm is currently using.

Another important point to consider when choosing the software is the type of analysis that needs to be performed. During the development of a project, the structural engineer may be required to make different types of analysis to the structure, such as dynamic, seismic, linear and nonlinear analysis. It is essential that the software meets the needs of the structural engineer.

There is a trend in the market for the analysis suppliers to move towards a one stop solution that is capable of providing the full range of analysis options (Autodesk,

2007). The selection of a broad and detailed single application will allow the full range of analysis challenges to be tackled directly without the need to keep updating the building information model between separate programs.

The Autodesk Revit Suite has a bi-directional link that grants the ability to easily transfer information with the most used structural analysis softwares in the industry, such as RISAFloor and RISA 3D by RISA, ETABS and SAP2000 by CSI, and RAM Structural System by Bentley.

The Revit - RISA Link

The use of an Application Programming Interface (API) makes possible the process of coming up with very adaptable analysis solutions for different types of structures. APIs are the core component that allows the transfer of data between the BIM software and the structural analysis software.

Autodesk has premier partners, like RISA, that have a technical staff available to interact with Autodesk personnel. This teamwork ensures that the link between the Autodesk Revit Structure and the RISAFloor and RISA 3D is constantly optimized.

When the link between Revit Structure and RISAFloor and RISA 3D is habilitated it adds a toolbar that facilitates both the exporting to and importing from RISA models. The link offers an exchange file tool that lets both Revit and RISA coexist on the same machine, accommodating to a variety of workflow situations.

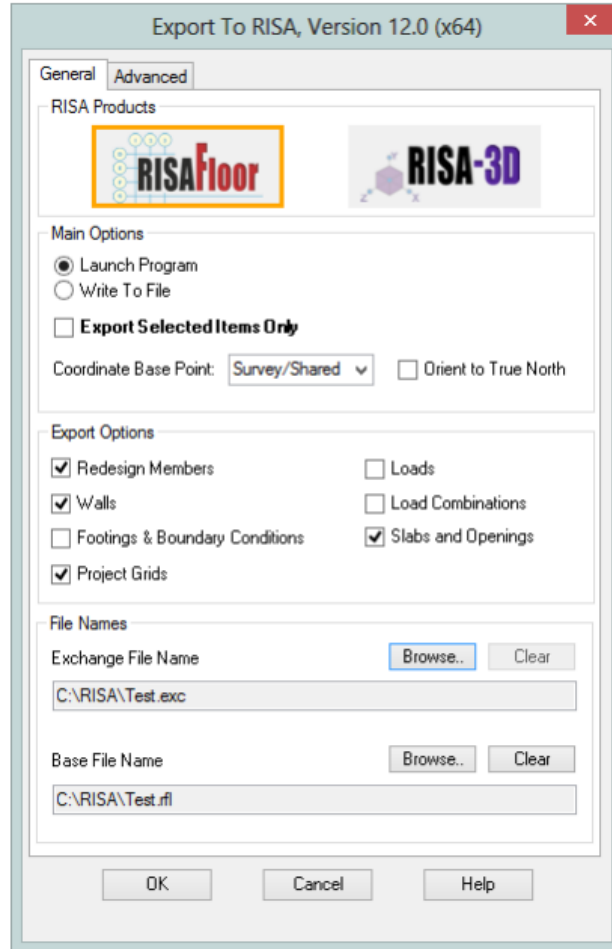


Figure 9. The Exchange File tool for Revit and RISA.

The link offers a variety of straightforward import and export options to maximize the control over the elements of the model that are transferred back and forth. An editable mapping file tool provides the ability to customize the link to support members and materials that are not included in the software, and a detailed log is constantly updated during every transfer to provide transparency and facilitate solving problems.

Case Study

The following case study analyses the Autodesk Revit and RISA 3D link. A simple three dimensional frame was created using Revit Structure. It consisted of seven beams, six columns, and four braces, for a total of seventeen members. W10x39 and W16x40 were used for the beams and columns, and L4x4 for the braces.

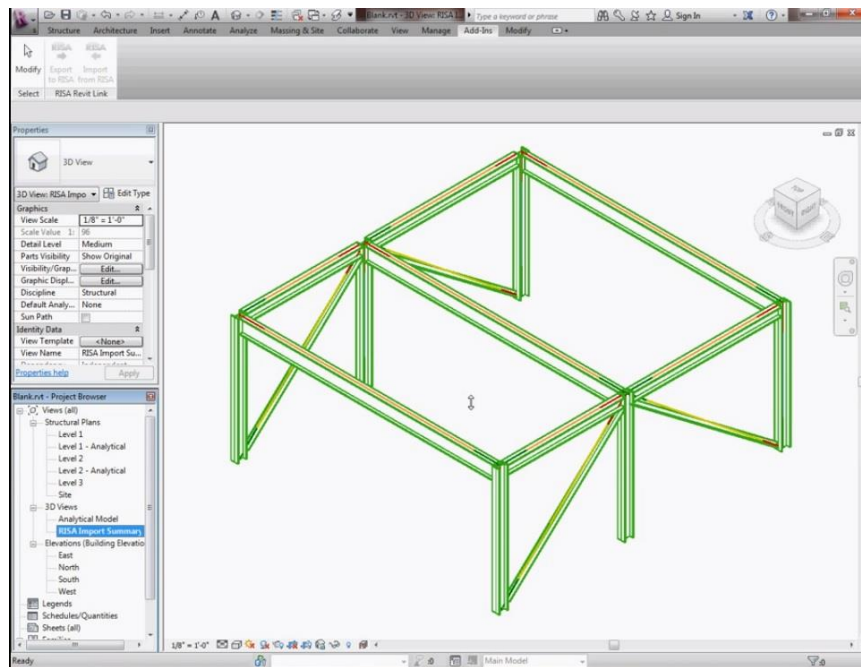


Figure 10. The render view of the frame in Revit Structure.

The model in Revit Structure was then used to create a brand new model in RISA 3D. To perform this task, the Export option was selected from the File tab, and then Autodesk Revit Exchange File was chosen. Using the Save Exchange File, and an exchange file was created to be later opened in RISA.

The RISA 3D software was then started, and the import new model option was chose, opening the Import menu, where import from Revit was chosen. The file previously saved was selected and a new RISA 3D model was created. It shows a progress bar when creating all the structural elements of the model.

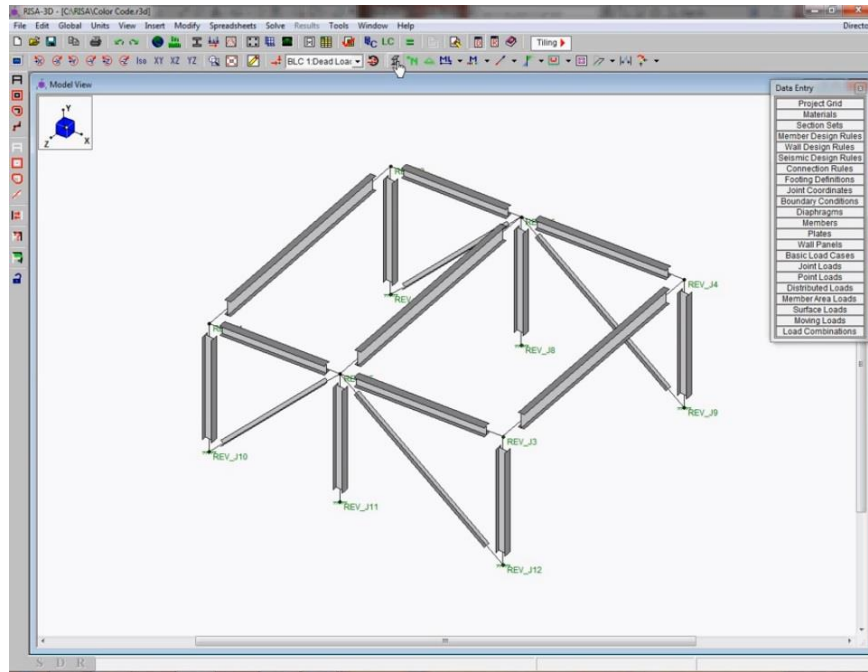


Figure 11. The render view of the frame in RISA 3D.

Once the process is complete, a RISA-Revit link reports shows up, with a list of all the members and materials that were added to the model. It is exactly the same model created in Revit. To complete the link, the file was saved in RISA.

Analysis and Results

The next step was to perform an analysis on the frame. A dead load of 1 k/ft, and a live and wind load of 5k were considered. The structure was solved for the envelope joint reactions. Once the analysis was completed, the design results were checked using

the AISC Steel Code. The results showed that the W16x40 beams of the frame are failing due to the load conditions on the structure. To solve this problem, the RISA suggested shape were used, changing the beams to W18x60.

The structure was successfully recalculated, with the new size of the beams fulfilling the requirements. To further increase changes to the members of the structure, another single angle was added in the other direction of the brace. Figure 12 shows the final result of the frame after the structural calculations were finished. The file was then saved, and exported to Revit Structure. All the information necessary is remembered from the first transfer. A new window shows the details of what was exported. The file was saved on top of the previous file, to guarantee that all the information was merged.

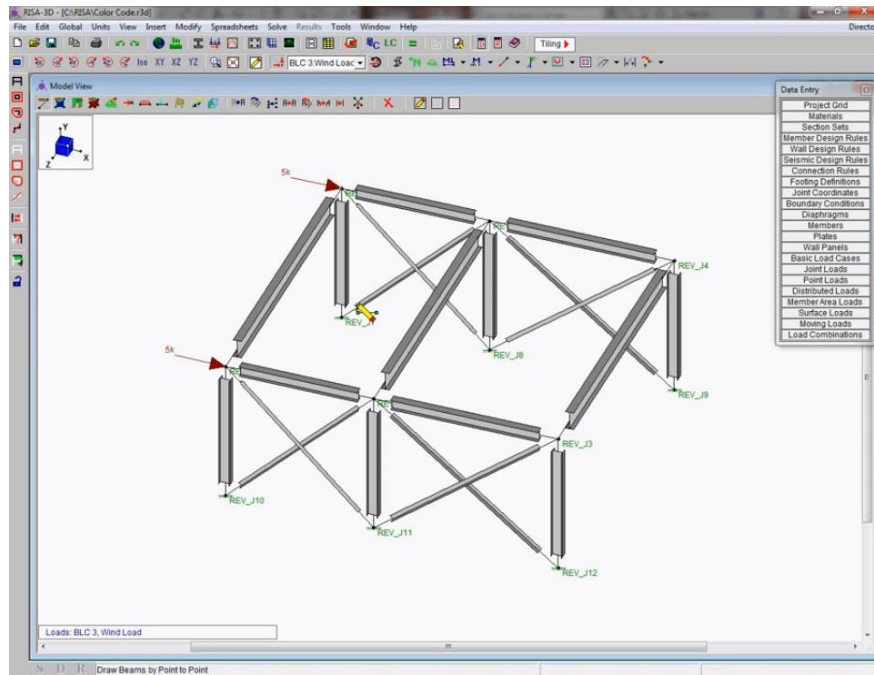


Figure 12. The frame after the structural design in RISA 3D.

The new updated model was then imported to Revit from RISA using the Exchange Tool. Revit then compares all the data of the model with the new updated version, showing everything that has been added or changed in the RISA model. The exchange report instantly shows that four members were added and three were modified. Figure 13 shows the new, color coded, updated model; it shows green for all the new members that were added to the model, and yellow for any changed member. All the other members that stayed the same are portrait black on the model. This gives a clear visualization of what was previously in the model and what was changed at the RISA model.

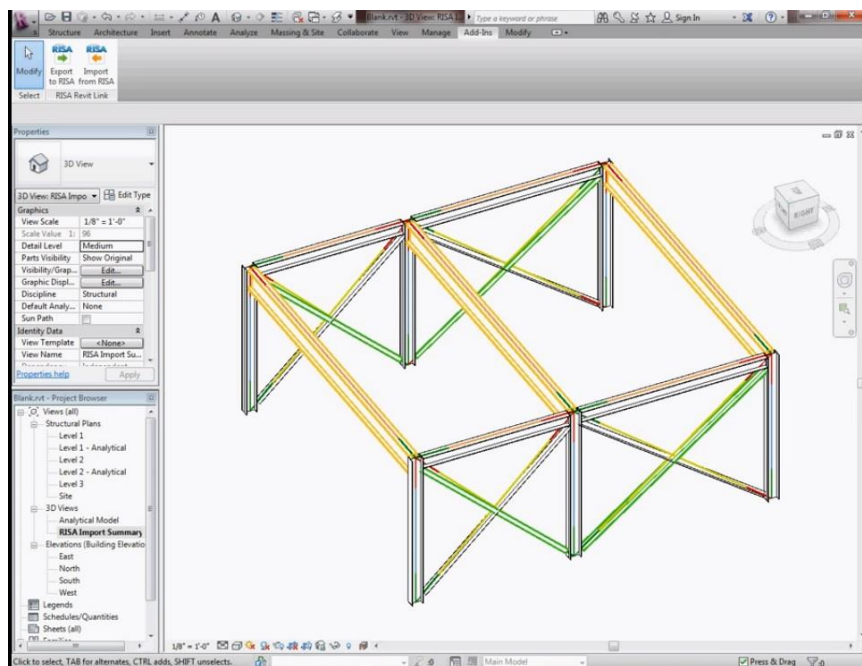


Figure 13. The frame after it was exported back to Revit Structure.

CONCLUSION

The architecture, engineering and construction industry is constantly on demand to produce work faster, at less cost and higher quality. Structural engineers are problem solvers and are constantly looking for new ways on how to apply technology to produce work. One of new methodologies that help today is building information modeling.

The benefits of using building information modeling are evident, especially when analyzing the way that this methodology enhances the structural design workflow. Engineers are realizing the power of BIM for more efficient and intelligent design, and most firms using BIM are reporting strong favor for this technology.

The increase in productivity is a significant benefit that BIM provides in structural engineering. Construction documents are generated completely automatic when using a building information model, significantly reducing the time required for detailing. It also reduces the need to make extensive checks, helping prevent errors in the documentation that can affect the construction.

Using the building information model not only enables the production of construction documents, but it also serves as a base to present the results from the structural analysis and design in an easy sharable way, keeping all the information regarding the analysis, design and documentation of a structural project in one place. A single building information model is used for both the analysis and the documentation phases, contributing to better coordination between the structural analysis results and the overall design, increasing consistency throughout the entire project. The improved

coordination can also be seen in better interoperability between team members' software's, allowing architects, structural and MEP engineers to manage a project more effectively.

The ability to create simulations and check different structural scenarios greatly help with analyzing a structure and taking decisions. This provides great project insight, enhancing its understanding and facilitating the process of solving problems and coming up with ideas. These visualizations can be used to present ideas in a more clear way, simplifying the process of explaining complex situations and helping teams communicate more adequately.

The case study developed in this report showed how the connection between the BIM software and the structural analysis software works. The seamless process of creating structural model in RISA from a design previously done in Revit Structure, and the ability to easy make changes and keep track of any alterations made throughout the model are a clear demonstration of the benefits that structural engineers can get form using this methodology.

The future of building information modeling is both exciting and challenging. The way that infrastructure projects are designed and constructed is constantly changing, and BIM is emerging as an innovative way to perform these duties. Even though BIM is a relatively recent development, more structural design professionals understand the potential benefits that can be realized through its use.

BIM will continue to transform the industry, with more structural and architectural firms recognizing the same opportunities, benefits and values. Clearly, the

question is not if BIM will succeed or fail, it is already working its way into projects. The challenge lies in trying to make the most out of all that BIM has to offer to structural engineering: improved productivity, coordination and visualization in analysis and design.

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