BIM in Structural Design Education

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ABSTRACT

This paper focuses on the experiences gained in introducing Building Information Modeling (BIM) in structural design education. Using BIM as a framework for teaching structural analysis and design, BIM tools were implemented as the primary approach for advancing other types of structural engineering knowledge that centers on digital practices. The research explores BIM tools in creating structural analytical models and the use of multiple analytical models to perform various structural analysis and design education tasks. These include the application of various tools and simulation practices to prepare a BIM model for conducting structural engineering design, such as beams, frames, trusses, slabs, foundations and finite element analysis.

The proposed BIM approach aims to develop deep learning about fundamental of structural analysis and design, promote collaborative thinking as a core activity, improve digital modeling and promote professional qualities to meet the demands of today's as well as tomorrow's integrated practice environments.

INTRODUCTION

Structural design and analysis in undergraduate curriculums mainly centers on mathematical computation, without emphasizing the importance of the overall concepts and behaviors of structural systems (Addis, 1990, 2001). Presently, in the education of structural engineers and architects, educators have inclined to focus predominantly on the classical approach of teaching structural design utilizing a linear sequence of courses such as statics, strength of materials, structural analysis, steel, wood, concrete and masonry design. Unfortunately, the interconnected nature of engineering design knowledge received rather less than their fair part of consideration

The process of designing building structure is normally interconnected with that of designing overall building. Building design decisions both govern and are determined by decisions on the structural system level. Since architects and engineers approach the design process in many different ways, a common ground for collaboration is critical for the success of designing building structures.

To promote other types of structural knowledge, this research centers on the interconnected aspects of structural design and how to utilize digital modeling to advance structural design education. In addition to the visualization of a geometrical shape or type of material of structural patterns, which can be done largely from memory, there is also the critical issue of understanding the overall building structure and the interactive design process (Nawari, 2013). The research aims to stress the value of digital modeling as it relates to understanding of the interconnected nature of structural design and behavior.

With current advancements in information technology, educators have variety of tools to explore in teaching principal of structural design. Particularly, Building Information Modeling (BIM) has the potential to promote attaining different types of structural knowledge learning objectives without compromising other basic principles requirements (Nawari et. al. 2011). BIM is a process that is fundamentally changing the role of computation in structural engineering by establishing a unified database of the entire building to be used for all levels of building structures from design to construction and beyond.

BIM has transformed the design and construction of buildings structures mostly due to its ability to postulate the interaction of various architectural and structural factors such as forces, deformation section properties, structural forms, and material strength, based on the nature of connections and supports. This study seeks to employ a BIM platform (Autodesk Revit, 2013) and their extensions, including Robot Structural Analysis software, to teach the fundamentals aspects of designing building structures and how to recognize the interrelationship between buildings and structural patterns and organization. This approach also strives for developing structural knowledge associated with the relationship to architecture. In other words the interdependence of architectural form and structure is emphasized for broader understanding of structure and design of building in general.

The research group includes three undergraduate architectural students (3^{rd} year) and three undergraduate students (3^{rd} year) from the College of Engineering, at the University of Florida to examine how BIM would advance learning and understanding of structural design. The research group was introduced to the fundamentals of BIM and BIM platform in about nine contact hours. The first phase comprised historical overview of Computer Aided Design (CAD) and fundamentals of BIM. The last part of this introduction was an overview of Autodesk Revit platform. Students are then assigned simple projects to improve their modeling skills using BIM platforms such as Revit in creating analytical and virtual physical models for various structural elements and patterns. Following this introduction students are exposed to various structure analytical tools that integrate with BIM platform.

Future engineers and architects should have solid and sufficient knowledge about the interplay between these disciplines. Thus, this research group aims to emphasis such dialog, which together with the creative skills of both disciplines will allow them to envisage and design magnificent buildings correctly.

BIM IN EDUCATION

Today, Building Information Modeling (BIM) in conjunction with the other emerging digital tools is transforming the way buildings and building systems are designed, manufactured, constructed, commissioned, operated and maintained. Decades of research into building modeling and simulating building systems have led to the modern state of practice. Rapid advancements in the ability to capture building elements information and create new knowledge from it is enabling stakeholders in the construction industry to develop and evaluate more alternatives with better inevitability and earlier in the design process, resulting in more integrated practice than ever before seen. Academia has to adapt to these rapid changes (Sharag-Eldin and Nawari, 2010).

Structural engineering colleges are challenged by the new technologies and require appropriate strategies for its effective integration and adoption. Many institutions are struggling to develop strategic plans and goals and institute a process for introducing BIM while upgrading core courses.

Engineering and architecture students have expectations that they will be appropriately equipped with the emerging technologies for their various subject disciplines, perceiving that this, alongside theoretical knowledge, will enhance their employment opportunities in the marketplace. BIM is certainly one of the critical paradigms that students are eagerly looking forward to learn.

STRUCTURAL DESIGN USING BIM

In practice, structural engineers typically start the design process by interpreting architectural drawings, creating design documentation, and creating numerous analytical models. These analytical models must be reliably coordinated with respect to general architectural layout, material and section properties, and loading. Once analysis and design is complete, the design documentation is modified to reflect the most current design. This workflow is repeated for each cycle of the design process. As a result, it becomes exceedingly critical to boost multidisciplinary education as well as setting up communication and knowledge sharing channels between architect and engineering students in order to advance design education as well as preserve and maintain the integrity of the design education. BIM platforms will enable such collaborative environment in teaching structural design.

The next sections will outline the approach followed in this research and how to integrate BIM in teaching structural design.

The Buildoid Concept

Without the traditional teaching emphasis on first understanding single elements such as beams, columns, bearing walls, etc., two dimensionally, using the laws of statics and strength of materials, this research utilizes BIM tools to help students create whole three dimensional structures and then investigate structural solutions. Students are allowed to use linear and non-linear elements as well as planar elements in modeling these three dimensional structural forms exemplifying various structural supports concepts including vertical and lateral resisting systems. These forms are referred to as “Buildoids” and they are primarily developed to stress the three dimensional nature, order, and organization of structural elements as well as to develop a sense of scale, proportion, and harmony.

Since building structures are three-dimensional, where the applied loads flow along the elements and connections to the external supports (foundations), introducing and emphasizing this fact early on in structural design education is the principal objective of the “Buildoid” concept. Examples of Buildoids are illustrated in Figure 1.

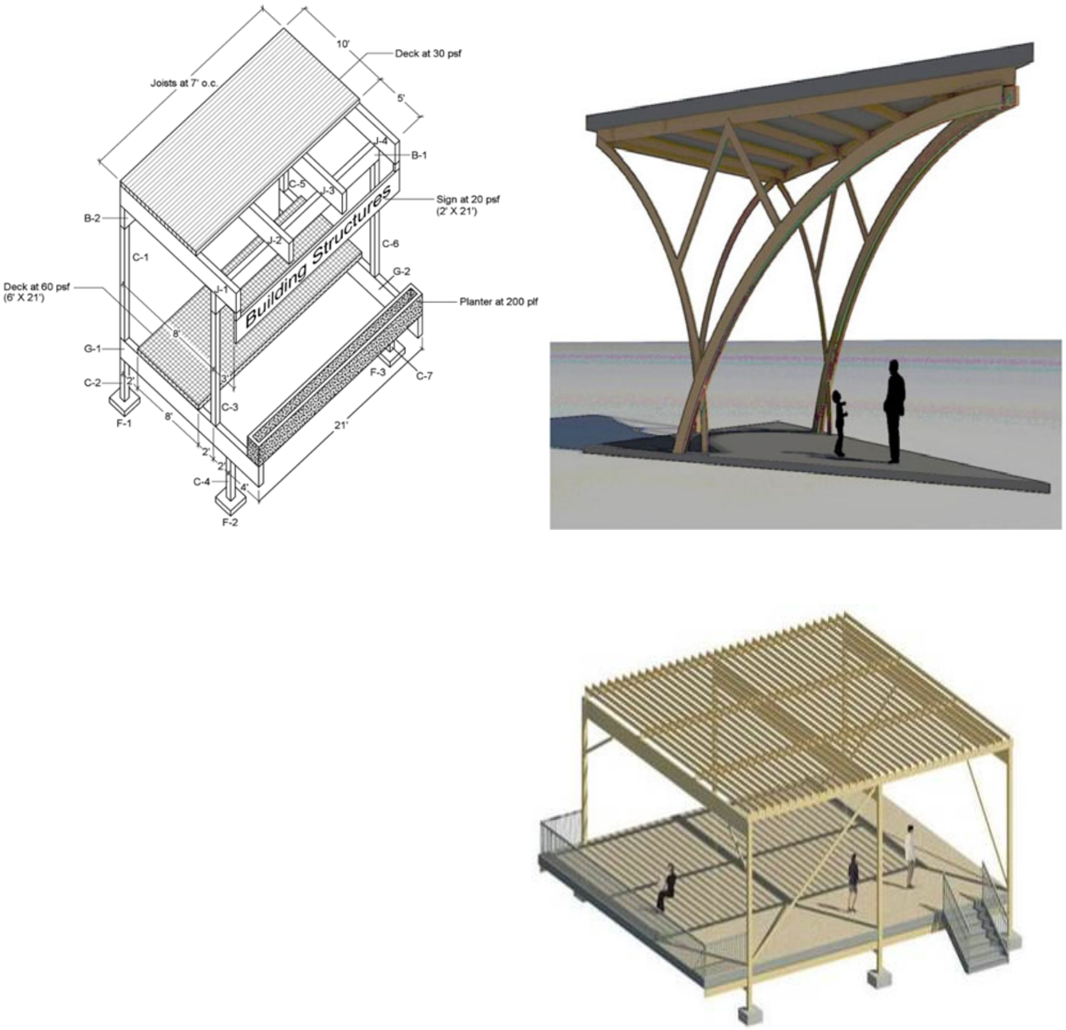


Figure 1. Example of Buidoids.

BIM tools are then applied to these buildoids to promote the understanding of fundamentals of structural analysis such as the force equilibrium, support reactions, shear force, and bending moment diagrams, frame and truss analysis, steel, wood, and concrete design. Figure 2 depicts the general project study approach while Figure 3 shows details about the various BIM structural analysis tools utilized in this study.

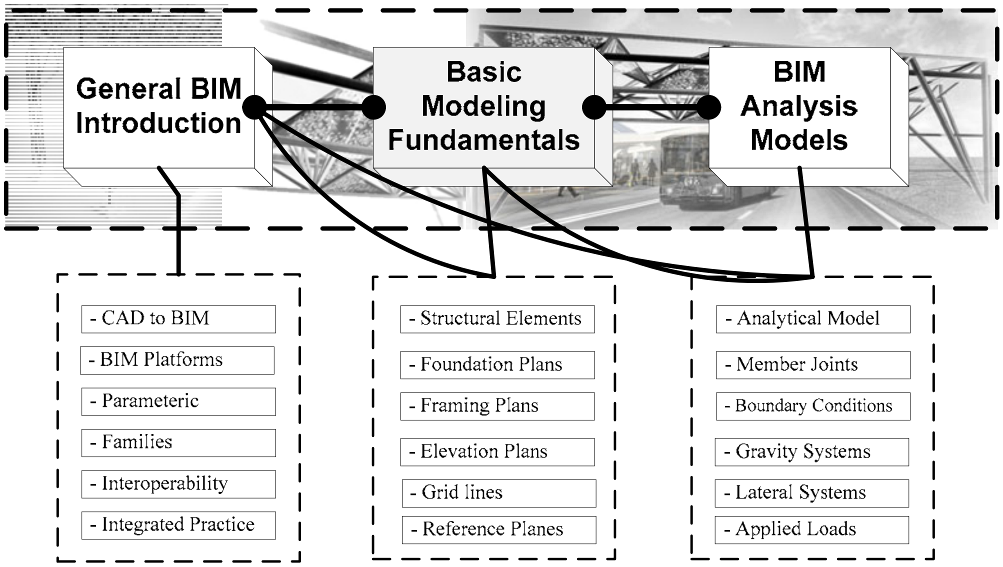


Figure 2. Outline of the BIM introduction.

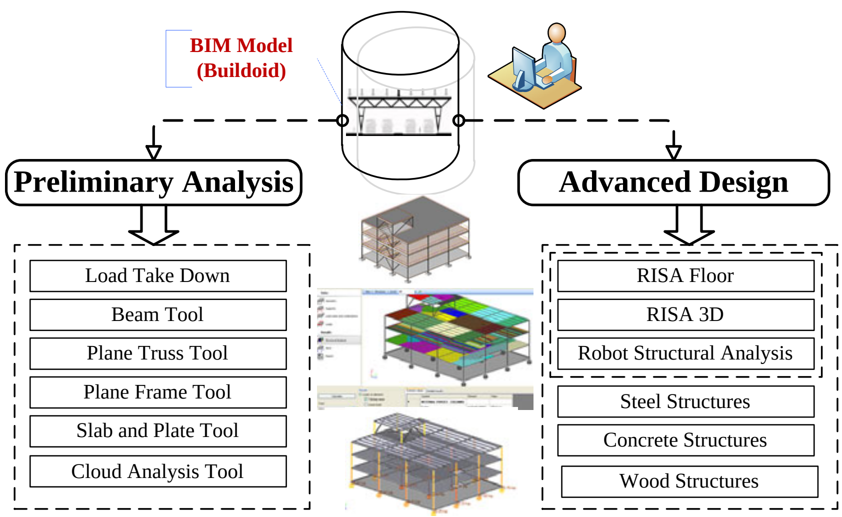
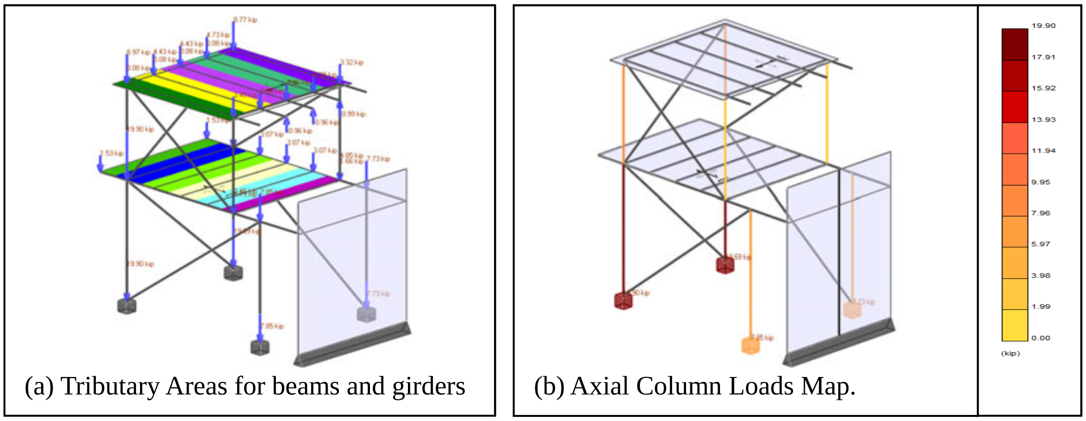


Figure 3. BIM Tools for structural design education.

The next section demonstrates this educational approach in structural design education.

EXAMPLES

The BIM platform along with its link to other structural analysis applications allow students to develop collaborative experience as they learn principal of structural design. The ability to select portions of the model and then send it to Structural Analysis programs, and vice versa is a powerful teaching approach. For instance, this flexibility allows students to work with the structure in separate analysis models, for example selecting a specific beam, slab, frame or a truss and send it to analysis tool. Figure 5 shows the analysis of a truss selected from the structural model, while Figure 4 depicts the load takedown results for the entire model. Students are then asked to verify these results using hand calculations.



(a) Tributary Areas for beams and girders

(b) Axial Column Loads Map.

Figure 4. Results from load takedown tool.

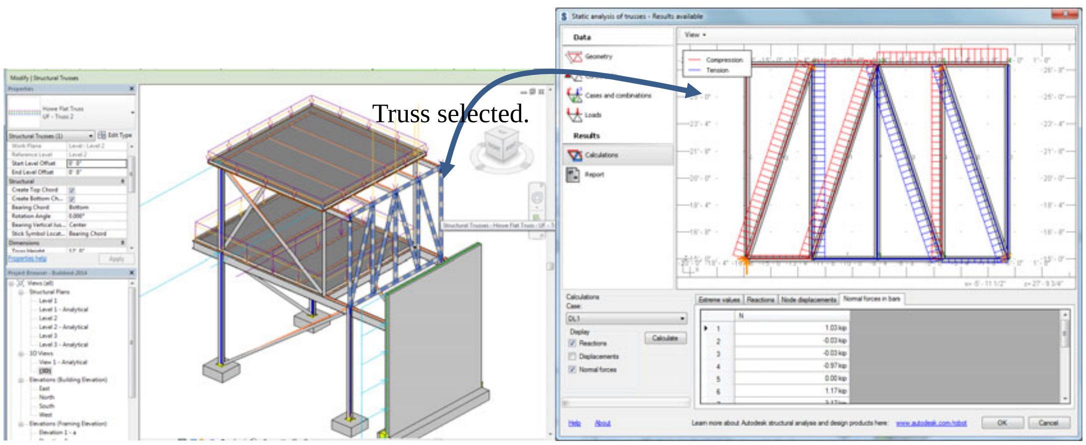


Figure 5. Truss analysis tool.

The advanced design education tools used in this research are RISA Floor, RISA 3D and Robot Structural Analysis software. These tools are linked and integrated with the BIM Platform and support interoperability workflow. Examples of the application of these tools are shown in Figures 6-8 demonstrating various results covering finite element, steel and concrete design.

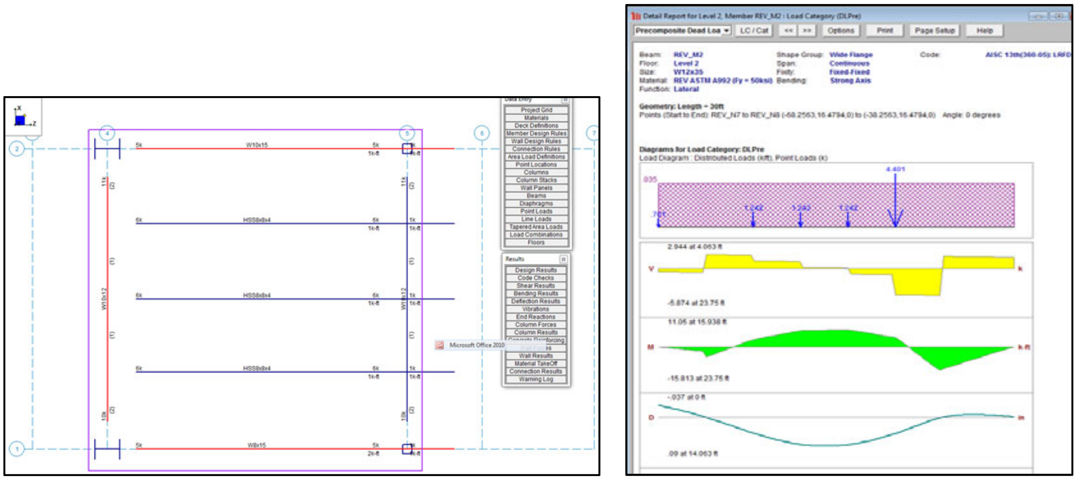


Figure 6. RISA Steel Design Results.

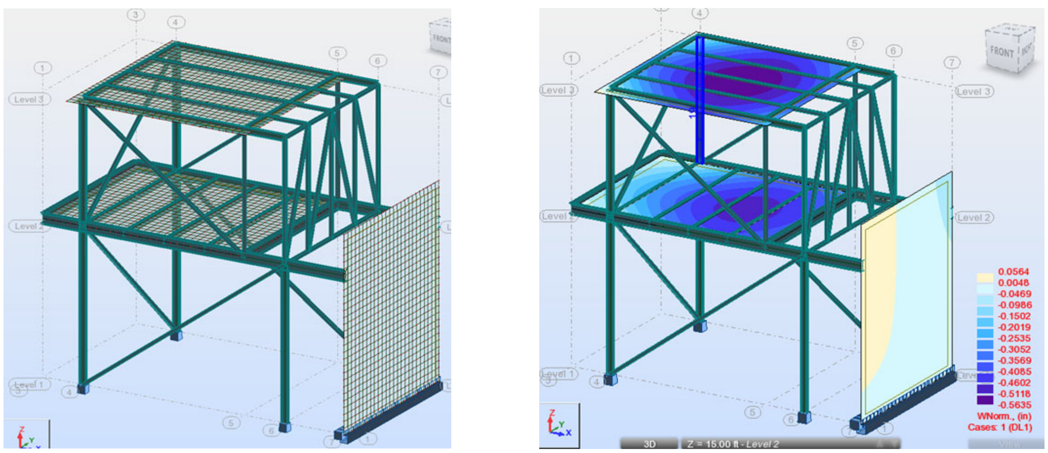
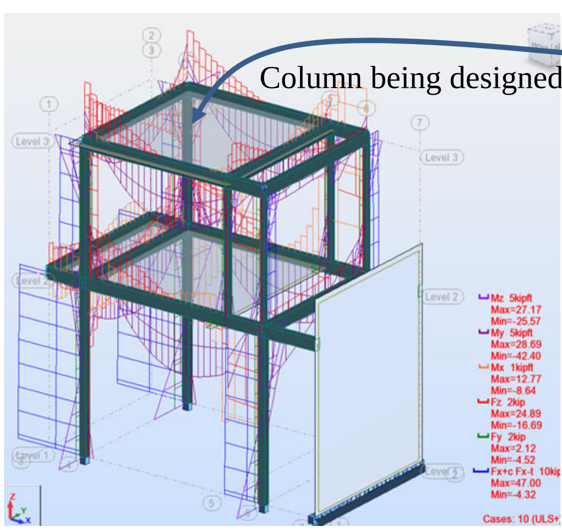


Figure 7. Finite Element analysis using Robot Structural Analysis.



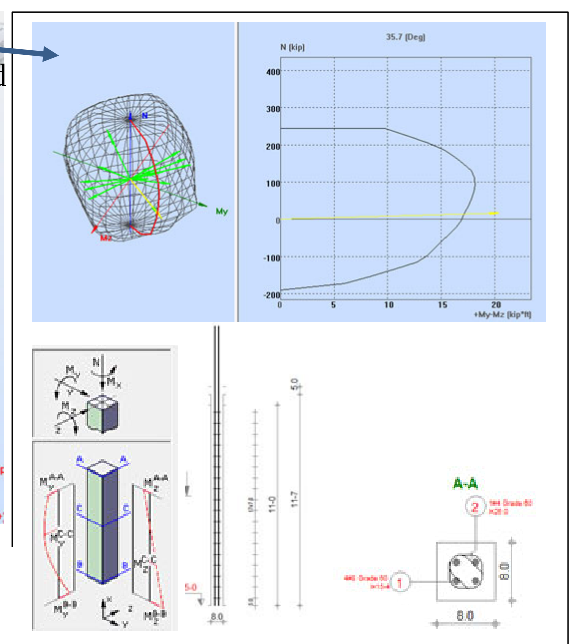


Figure 8. Concrete analysis and design using Robot Structural Analysis tool.

CONCLUSION

The process of designing building structure is normally interconnected with that of designing overall building. Since architects and engineers approach the design process in many different ways, a common ground for collaboration is critical for the success of designing building structures. Building Information Modeling (BIM) offers a collaborative solution and advance structural knowledge learning without compromising other principles of structural design. The research aims to stress the value of digital modeling in education as it relates to understanding of the interconnected nature of structural systems and behavior.

This research employed BIM platform and their extensions to teach the fundamentals aspects of designing building structures and how to recognize the interrelationship between buildings and structural patterns and organization. This approach also strives for developing structural knowledge associated with the interdependence of architectural forms. The proposed Buildoid framework provides a balanced and coherent teaching approach that aims to convey the creative thinking as well as the engineering laws that are truly the basis of every aspect and every stage of designing building structures using BIM platforms. It focuses on how to motivate and challenge students' fundamental understanding in the context of a creative process that illustrates theory as well as reality.

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