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BIM Application in Steel Structures - Case Study

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ABSTRACT

The impact of building information modeling (BIM) on construction projects is a significant issue that the construction industry is currently dealing with. BIM is an emerging technology that is expanding quickly and gaining acceptance in the construction sector. Although it's a developing technology, it is not currently being used to its full potential. Through the analysis of a case study, this paper investigates the deployment of BIM at each stage of the steel structure implementation and the advantages that have arisen from it. It was discovered that effective BIM software utilization might lead to structures with superior quality, lower costs, and quicker completion. The case study provided insight into how BIM might streamline and clarify the construction as it moves forward. Information-sharing coordination is crucial throughout all stages to optimize the efficiency of the utilization of BIM in the construction of steel structures.

Introduction and Background

Building information modeling (BIM) is a developing technology in the architectural, engineering, and construction (AEC) industry. BIM has completely transformed the construction sector and is now an important subject of conversation in every AEC-related organization due to the advantages that may be attained when this technology is used (Hu, et al. 2016). In the AEC sector, data management and cooperation are highly difficult due to the many stakeholders from multiple disciplines, diverse teams, and technologies concerned, as well as the multi-phased and transitional behavior of projects. The lack of interconnection and compatibility continues to result in obstacles to data transmission, even though BIM is intended to facilitate this type of cooperation. This is thought to be the biggest barrier to the broad implementation of BIM in the AEC sector, particularly for steel structure projects (Hu, et al. 2016). Steel structural projects are a comparatively specialized category of construction work that deals with the planning and erection of various project components for a variety of functions. These projects differ from traditional structural engineering projects primarily in the unique challenges that must be taken into account during construction, transportation, installation, and operation (Abdel Rashid, Aboul Haggag and Elhegazy 2015). The ability of the information generated by different stakeholders at every stage of the steel structure project to be properly shared or exchanged across the entire structure's lifetime is essential for the collaborative use of BIM tools. In the steel building sector, information transmission continues to be a crucial but challenging responsibility. In order for a project to be successful, users at various phases of the process must communicate with one another and share information. The adoption of new technology could result in fundamental shifts in perspective (Froese 2003). The software's internal capabilities and characteristics, transmission of data, and connection protocols between various software must be taken into account while using BIM to build a structure (Pazlar and Turk 2008). For revolutionary structures, designers ought to pick innovative technologies, suitable materials, and robust systems (Zhong, Elhegazy and Elzarka 2022). As a methodology, BIM is described as a collection of interrelated regulations, procedures, and tools that enable the management of critical building design and project data in digital format across the course of a building (Succar, Sher and Williams 2012). This methodology has the potential to revolutionize how buildings are planned, built, managed, and demolished. It has also been seen as an inspiration for the adoption of innovative strategies in the AEC sector. BIM technology acts as a descriptive method for the practical aspects of steel structure projects and the digitalization of the actual execution of physical structures. The idea behind BIM technology is to create a digital collection of data across the project's life cycle in order to realize information exchange and integration between multiple phases and multiple disciplines and achieve a complete overview of the project's development (Zhenguang 2021). BIM is a collaborative tool utilized by any professional involved in the AEC industry. It depends on a variety of software options. For the whole life cycle management of the building, including its deconstruction, BIM contains all the structure's elements, including their geometry, spatial connections, attributes, and amounts. One of the key benefits of this kind of operation is that different AEC design participants can use physical or reference models from their teammates without needing any specific expertise in the industry. It is possible to initially coordinate the incorporation of the services and structure designs by only comparing the items from both schemes to ensure that there are no conflicts (Robinson 2007).

BIM has attracted the attention of the construction industry over the past two decades due to numerous advantages and savings in resources it provides throughout design, planning, and construction. (Barlish and Sullivan 2012) investigated the advantages of BIM by creating an approach that evaluated the technology's advantages and offered measurements for its impact on project efficiency. They proposed a framework that relied on the study of a number of case studies, some of which used BIM technology and others using conventional techniques. In light of that, a calculating model was created while taking into account economic factors. The results showed that there is considerable opportunity for BIM advantages to be realized in the tool installation department of semiconductor manufacturing. (Hu, et al. 2020) suggested optimizing the conflict correction procedure utilizing BIM network theory to enhance clash resolution. To reduce feedback dependability, which could lead to design rework on a project, they created an optimization algorithm for figuring out the best order according to a conflicting dependency network. They discovered that the optimized sequence greatly decreases feedback and dynamically clusters dependent collisions, which improves the coordination of the design. (Mangal, et al. 2021) introduced a novel method to automatically improve the clash-free steel reinforcement design employing two-phase genetic algorithms and BIM. They discovered that the suggested method enhances the handling of clashes between steel reinforcements during the design stage and can be used to investigate the clash-free arrangement and size combination of reinforcement steel in RC frame structures, meeting the specifications of the code of design employed on construction sites. (Disney, Roupe' and Johansson 2022) investigated the fundamental idea and encompassing strategy of a Total BIM project to promote the adoption of BIM strategy development. They came to the conclusion that the Total BIM concept depends significantly on the close connections between separate BIM uses. Effective leadership, cloud-based model management, easy-to-use on-site mobile BIM applications, and production-based BIM were the four vital success elements that were discovered. (Hernández, et al. 2021) offered an approach to architect-oriented design by reducing construction expenses and employing computational design to create a preliminary layout for residential buildings with the normal shape of steel structures. They discussed the use of a genetic algorithm for multiple criteria optimization in the computational design process of the structural construction grid. They discovered that the BIM model permits linking the outcomes of parametric design and enhancing data clarity. That gives a basic plan that might be greatly modified in later stages in collaboration with the structural engineer without redoing the structural grid fit. (Robinson 2007) addressed the current status of BIM from a structural perspective, taking into account the switch from 2D to 3D alternatives. Also taken into consideration are open interfaces and how they make BIM data accessible to software tools other than specialized modeling solutions, promoting stronger design team cooperation. He discovered that the structural BIM solution must be a completely open, adaptable solution that enables contemporary computer architecture to fulfill the needs of the engineering design platforms. (Mellado and Lou 2020) investigated and evaluated prior work on a potential framework for integrating BIM, lean, and sustainability concepts to encourage performance enhancements. The motivations, advantages, limitations, and obstacles were examined. The findings demonstrated that BIM, lean, and sustainability shared crucial success elements, including cooperation, teamwork, training, proactive engagement, dedication, and competent staff.

Although numerous studies have explored the incorporation of BIM in construction projects, there is a relative shortage of academic studies on BIM application on steel structures. Through the review of a case study, this paper investigates the application of BIM at every phase of the steel structure implementation and the resulting benefits.

Research Methodology

As was demonstrated in the previous section, an analysis of pertinent literature was performed. Then, an actual steel structure was used as a case study for examination and analysis. Lastly, conclusions regarding the techniques for integrating BIM into steel structures were defined. The research methodology is displayed in Figure 1.

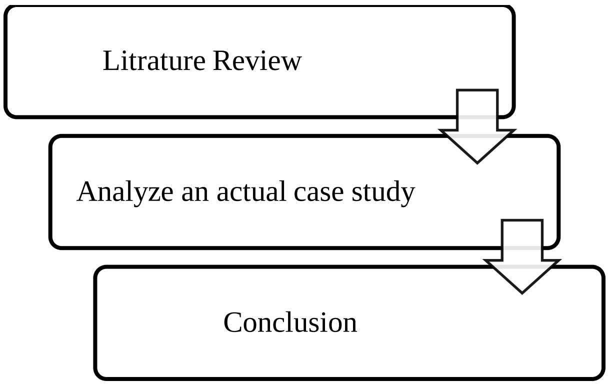

Fig 1. Research methodology

Case study

A city entrance gate made of steel was considered as a case study. The following are the structure's characteristics:

- Width: 26 m.
- Height: 12.4 m
- Structural system: space truss supported by concrete columns.

The incorporation of BIM in the processes of the steel structure, indicated in Figure 2, is demonstrated in the subsequent sections.

Fig 2. The steel structure processes

BIM in the architectural design stage:

The design stage is the initial step in any construction project; it comes before any other construction activity and has a significant impact on the budget, the timeline, and the manner of construction (Elhegazy, Chakraborty, et al. 2022). When evaluating designs for structures in the initial design phase, the construction design team encounters a number of decision-making challenges (Elhegazy, Ebid and Mahdi, et al. 2021). Visualization and 3D modeling simulation are the two main benefits of BIM at this stage and have a significant impact on architectural design. It can help the staff comprehend the fundamentals of design and identify the numerous information and documents related to project development (Zhenguang 2021). Figure 3 displays the architectural design drawing. BIM makes it possible to clearly integrate and save the results of architectural design in models. The ideal approach would be an automated feedback interaction between architectural design and structural design. As the architect updates the design requirements, they are accommodating to the structural design. Additionally, the interaction between them permits the creation of a BIM model, which facilitates the archiving, maintenance, and exchange of data with different disciplines (Sacks, et al. 2018).

BIM in the structural design stage:

The primary objective of the structural designer is to choose the most efficient structural system at the most economical cost (Elhegazya, et al. 2020). Linking structural and architectural BIM models is a significant approach that helps in the implementation of intelligent incorporation, and these should always be accessible as reference models (Robinson 2007). Establishing the structural model is one of the most elementary tasks because it requires the release of construction blueprints, in-depth modifications, and expense budgets. The benefits of BIM technology are clearly visible during the creation of the structural model (Zhenguang 2021). Using SAP2000 software, a thorough structural analysis was completed in this phase, resulting in a 3D model with a specified structural design and 2D structural drawings that detail the structural sections of each element. At this phase, analysis and design are crucial in the integration of the structures that carry loads into the model. The cost savings are strongly impacted by the design optimization of steel structures (Elhegazy, Ebid and AboulHaggag, et al. 2023). The optimization strategies cut down on expenses, speed up the process and simplify the essential design (Salah, et al. 2022). Adjustments are carried out instantly in the structural BIM model, as parametric elements are capable of adapting and responding to modifications, and all analysis outcomes are modified consequently (Robinson 2007).

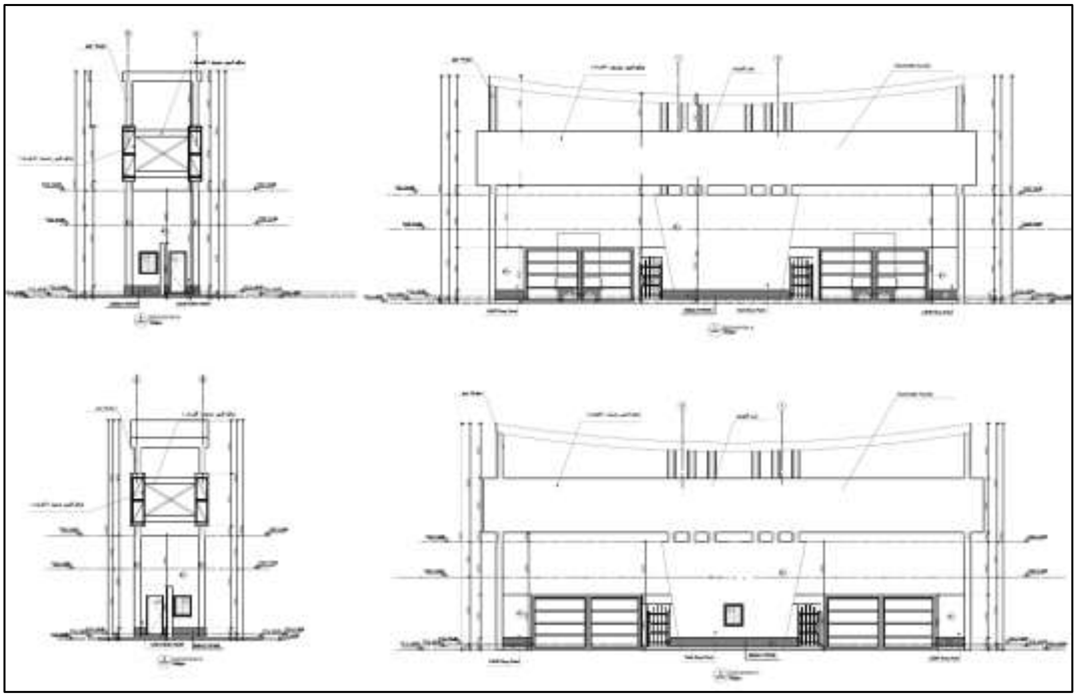

Fig 3. Architecture design drawing

BIM in the detailing stage:

A thorough model was generated using the Tekla Structures software, which also contained modeling for connections and steel section specifications for every element, as shown in Figure 4.

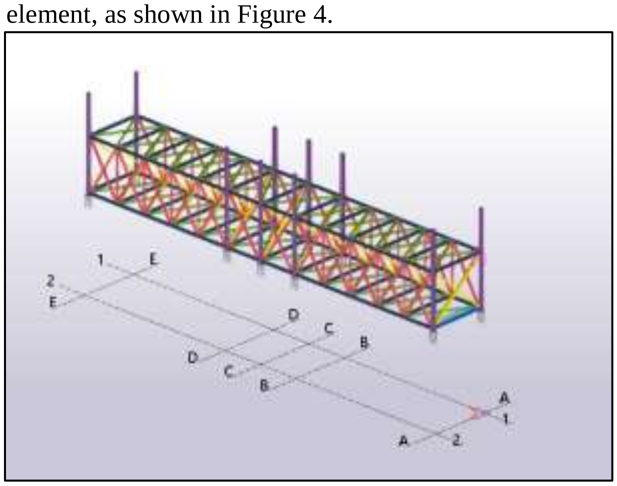

Fig 4. Detailed model by Tekla

The assembly drawings required for manufacturing and installation were produced using the detailed model, as shown in Figure 5. The quantities and expenses for each element can be computed rapidly and precisely using the BIM information database, which is more compatible with the national standards for producing prefabricated assemblies (Zhenguang 2021). Material lists and part lists which were used for quantities and cost calculation are presented in Figures 6 and 7. The BIM technical team initially utilizes the application to simulate the entire 4D model and the information for multiple elements. That could make it simpler for the construction team to better understand the complexity of the project and remove some unneeded elements (Zhenguang 2021).

BIM in the clash detection:

The ability to connect diverse software models, evaluate results, and exchange project information across disciplines and phases in a federated model is a significant benefit of adopting BIM. As a result, improvements can be immediately realized, including identifying and resolving challenges and conflicts before starting the construction stage (Hu, et al. 2016).

BIM in the construction stage:
Following the completion of the theoretical demo utilizing the federated model of BIM technology, the manufacturing and zero-error construction are performed using the BIM management system.

BIM has many benefits throughout the construction phase, including construction simulation, environmentally optimized performance, security, development, immediate feedback, automation, handling suppliers, and site arrangement. The adoption of BIM technology during the construction of steel structures may more effectively guarantee synchronization between the steel structure production and structural design, as well as a clear relationship connecting the computational model of steel structures and the information on structural design (Zhenguang 2021). After construction, building operations and maintenance can be performed using BIM project data.

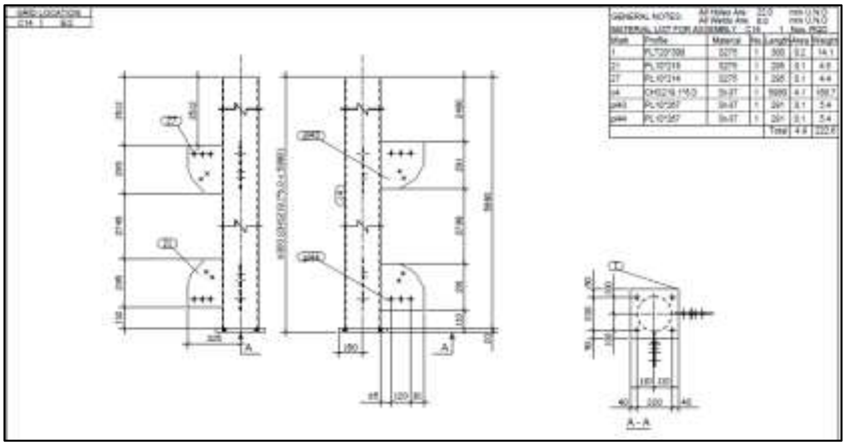

Fig 5. Assembly drawing

Project Number:	500-103
Project	Tekla Model
Date	08/28/2023 17:27:14

Profile	Grade	Qty	Length(mm)	Net Area(m^2) for one	Net Area(m^2) for all	Net Wieght(kg) for one	Net Wieght(kg) for all
CHS219.1*6.0	St-37	1	5950	4.11	4.11	186.05	186.05
CHS219.1*6.0	St-37	9	5980	4.13	37.14	186.98	1682.86
	Total	10	59770		41.24		1868.90
FLT10*300	St-37	64	294.15	0.18	11.70	6.72	430.41
FLT10*300	St-37	32	337.45	0.20	6.30	7.28	232.42
	Total	96	29623		18.01		662.83
FLT20*300	S275	10	300	0.20	2.04	14.13	141.30
	Total	10	3000		2.04		141.30
L60*6	St-37	8	1660.01	0.39	3.09	8.91	71.31
L60*6	St-37	8	1661.4	0.39	3.10	8.92	71.37
L60*6	St-37	8	1668.44	0.39	3.11	8.96	71.67
L60*6	St-37	8	1675.6	0.39	3.12	9.00	71.98

Fig 6. Material list

Project Number:	500-103
Project	Tekla Model
Date	08/28/2023 17:27:43

PartPos	Profile	No.	Material	Length (mm)	Area(m^2)	Weight(kg)
1	FLT20*300	10	S275	300	0.2	14.1
2	ROD20	40	S275	857	0.1	1.9
b42	L60*6	19	St-37	3450	0.8	18.7
b43	L60*6	14	St-37	3450	0.8	18.7
b44	L60*6	3	St-37	3450	0.8	18.7
b47	L60*6	2	St-37	3450	0.8	18.7
b48	L60*6	2	St-37	3450	0.8	18.7
b49	L60*6	2	St-37	3450	0.8	18.7
b50	L60*6	3	St-37	3450	0.8	18.7
b51	L60*6	3	St-37	3450	0.8	18.7
b52	L60*6	3	St-37	3450	0.8	18.7
br54	L60*6	4	St-37	1677	0.4	9.1
br56	L60*6	4	St-37	1676	0.4	9.1
br58	L60*6	4	St-37	1661	0.4	9.0

Fig 7. Part list

Conclusion
According to the understanding obtained from the case study and the literature review about the incorporation of BIM technology in the construction processes of steel structures, the development of BIM technology is a significant advancement in the field of steel structure engineering construction and also increases the employees' information. It may simplify and

clarify the construction as it proceeds. Complete BIM integration in the execution of steel structures enables expense and resource savings. BIM is a multidisciplinary collaborative strategy that integrates tools, processes, and software to assist stakeholders in breaking down boundaries. To maximize the effectiveness of BIM implementation in the implementation of steel structures, information-sharing collaboration is essential during all phases. Model-enabled interoperability could be significantly improved, updated, and expanded with the development of BIM applications.

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