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# Conversion Challenges: A Case Study of Converting a Post and Lintel Structure to a Precast Concrete Structure Using Building Information Modeling (BIM)

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## ABSTRACT

Building Information Modeling (BIM) is now a widely accepted tool in the construction industry for designing and managing construction projects. However, converting a BIM model from one type of structure to another can be challenging. This case report aims to document the problems and challenges encountered when an engineer team attempted to create a precast concrete structural BIM model from an architectural BIM model that was initially designed to use a post and lintel system. The architect worked with the engineer team, facing several challenges when changing the structural system. One of the main challenges during the conversion process was redesigning structural elements as the structural behavior of the building changed significantly. The architectural layout and design of the building had to be altered to accommodate the new structural system. Additionally, the mechanical, electrical, and plumbing (MEP) systems had to be planned for installation within the precast concrete structure. These changes required significant effort and coordination between the different teams involved in the project. In conclusion, the case study demonstrates that converting a BIM model from one type of structure to another can be a challenging task that requires significant effort, coordination, and planning. It also shows that BIM models are not just a design tool but also a powerful tool for construction management and coordination.

***Keywords:*** building information modeling, BIM, precast concrete, prefabrication, BIM conversion

# INTRODUCTION

Building Information Modeling (BIM) is a process of digitizing building objects that includes not only its physical characteristics but also its functional characteristics (International Organization of Standardization [ISO], 2018; National Institute of Building Sciences, 2007). This process allows for the integration of all aspects of the design and construction of a building, from architectural design to construction and building operation. Currently, BIM is increasingly accepted as a tool in the construction industry for designing and managing construction projects (Wong et al., 2009). One of the key reasons for its popularity is its ability to be used for visualization and collaboration among different parties involved in a construction project such as architects, engineers, and contractors, resulting in fewer errors and delays (Sacks et al., 2018; Underwood & Isikdag, 2009). BIM also enables more accurate cost and time estimates, and, post-completion, it facilitates the maintenance and operation of the building. Furthermore, BIM allows for identifying potential issues and conflicts before construction, preventing mistakes and saving time and money (Sacks et al., 2018). BIM enhances the construction process by reducing project duration (Jang & Lee, 2018), reducing project costs (Seadon & Tookey, 2019), enhancing field labor productivity control (Lee et al., 2017), and refining design productivity (Zhang et al., 2017). The degree of improvement varies from one project to another and cannot be universally applied; however, some case studies have reported that BIM has the potential to enhance overall productivity by approximately 36% (Collins, 2016). In a broader context, the utilization of BIM enhances efficiency, effectiveness, flexibility, and innovation within the design and construction industries (Takim et al., 2013).

In principle, a BIM model is created early in the design phase, and it will be developed by adding more details in the following phases. However, converting a BIM model from one type of structure to another can be a challenging task. This paper aims to document the problems and challenges encountered in the conversion of a post and lintel BIM model to a precast concrete BIM model in a real building construction project. The use of precast concrete is a prefabricated construction method where concrete elements are cast in a factory and then transported to the building site for installation (Elliott, 2019). This method offers many advantages such as increased accuracy, faster construction, and improved quality control. This is because precast concrete elements are manufactured in a controlled environment, which ensures that the concrete is of a consistent quality (Priya & Neamitha, 2018).

In this case study, a BIM model was initially designed as a post and lintel structure, but was later converted to a precast concrete structure. This process required changes not only to the structural system, but also to the architectural details. The mechanical, electrical, and plumbing (MEP) system also needed to be carefully planned and coordinated. This paper explores the challenges faced during this conversion process and how BIM was used to overcome them. It will provide insights into the benefits of using BIM in the construction industry and the importance of considering different structural systems early in the design phase.

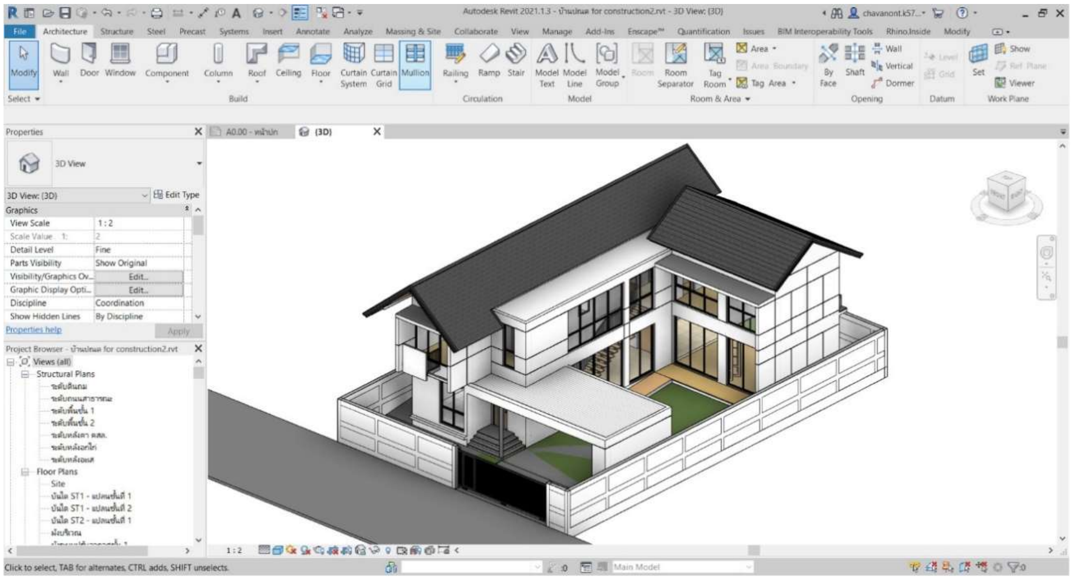
# METHODOLOGY

## Case Study Overview

The case study presented in this paper is a 2-story house with a total area of 316 square meters. The house is designed in an L-shaped layout with a gable roof. The land size of the property is 400 square meters, and the budget for the construction project is around 7 million Baht. The author of this paper is the architect who was responsible for the architectural design. The architectural model was created using Autodesk Revit 2021. The original design of the house created in Autodesk Revit is shown in Figure 1.

**Figure 1**

*The Original Design of the Case Study*



The house was initially designed as a post and lintel structure, and the engineering team completed the structural, electrical, and MEP design used for preparation of the construction permission documents. However, the owner later decided to use a precast concrete structure based on a suggestion from the contractor, who has an in-house engineer. Therefore, converting post and lintel structure to precast concrete structure is the responsibility of the contractor. Even so, the contractor's engineering team of the works with the architectural team in the conversion process because some architectural design has to be changed and MEP system has to be synchronized with architectural and structural design. The benefits and drawbacks of this method of construction are discussed in the next section.

## Precast Concrete Selection and Limitations

Prefabricated construction is a process where components of a construction project are created in a factory before being transported to the construction site for assembly (Sparkman et al., 1999). Prefabricated construction can be categorized into 4 categories (Gibb & Isack, 2003). Category 1 is component manufacture and sub-assembly, which involves manufacturing and assembly of prefabricated parts such as doors, windows, bricks, or tiles that are always made in a factory. Category 2 is non-volumetric pre-assembly, which involves production and installation of building parts that do not create usable space such as structural frames, structural cladding wall panels, or bridge units. Category 3 is volumetric assembly, where the usable spaces such as a unit of a bathroom or kitchen are produced in the factory before being assembled on-site. Category 4 is modular building, where the usable spaces are produced in the factory and assembled as the actual structure of the building.

In this case study the design of the house is converted from a post and lintel structure cast-in-situ to a precast concrete load-bearing wall structure. Precast concrete is a type of prefabricated construction in which concrete elements are cast in a factory. These concrete elements, which are categorized as prefabricated construction category 2, can be columns and beams for post and lintel structures or walls for load-bearing wall structures.

The decision to switch from a post and lintel structure to a precast concrete structure was made due to the advantages offered by the precast structure (Priya & Neamitha, 2018). One of the main benefits of using precast concrete is the faster construction time. By manufacturing the elements off-site, the time needed for on-site casting and curing is reduced. The contractor claimed that, for this building, the structural part could be completed within one month. Additionally, the use of precast concrete improves the quality and consistency of the final product as concrete elements are manufactured in a controlled environment. Another benefit of precast concrete is precast concrete offers cost-effectiveness by reducing on-site labor costs. Lastly, precast concrete walls have a better thermal insulating property than brick masonry walls, resulting in improved energy efficiency.

However, precast concrete also has some disadvantages or limitations. One of the main drawbacks is the higher cost when compared to conventional construction methods (Priya & Neamitha, 2018). The owner and the architect compared the cost estimations between precast concrete construction and conventional construction and found that precast concrete is approximately 10% more expensive. The data used in the cost estimation comparison was collected through an assessment of the Bill of Quantities (BOQ), obtained from the bidding process. The evaluation involved a comparison of the bid prices submitted by three different contractors. Two of these contractors employed conventional construction methods, while the third contractor utilized the precast concrete method. It is important to note that one of the contractors that used the conventional method submitted an unusually low bid price that did not include elements such as aluminum doors and windows, rendering a direct comparison invalid. To ensure accurate comparison, the remaining contractors who used the conventional construction method were pitted against the contractor employing the precast concrete method. This comprehensive assessment revealed a cost difference between the two approaches. Still, the owner chose to use precast concrete because it allows for faster construction and more reliable quality control. Another limitation of precast concrete relates to design flexibility, as the design of precast concrete elements is constrained by the manufacturing and transportation process. Additionally, transportation and installation of precast concrete elements can be challenging, as they can be heavy and difficult to transport, especially for sites with limited access. Lastly, once precast concrete elements are installed, they are difficult to modify on-site.

All in all, the use of prefabricated construction, specifically precast concrete, offers several advantages such as faster construction times, improved quality and consistency, and cost-effectiveness. However, it also has some limitations such as higher costs compared to conventional construction methods, limited design flexibility, and transportation and installation challenges. Despite these limitations, the owner and architect of the case study chose to use precast concrete due to its benefits. The construction team had to collaborate closely with the architectural team to overcome any challenges during the conversion process, which is discussed in further detail in the next section.

# RESULTS

## Conversion Challenges

The conversion of the post and lintel structure to a precast concrete wall-bearing structure presented several challenges in this case study. These challenges can be divided into three building systems: the structural system, the architectural system, and the MEP system. The use of BIM technology played a crucial role in connecting the challenges with solutions by allowing interactive teamwork, visualization, and adjustments on the go. The project's successful completion shows that the strategies used were effective, highlighting practical problem-solving matters in a real construction situation.

### Structural Issues

One of the main challenges encountered was the need to change the structural system. In this case study, the original structure was a post and lintel (framed) system, while the new structure was a wall-bearing system using precast concrete. This required a complete redesign of the structural engineering part.

The original design had a cast-in-place reinforced concrete (RC) structure, consisting of piles, footings, columns, and beams. The piles were 320 mm diameter bored piles; the footings supported either one or two piles, and the columns had either rectangular or circular shapes. The beams were rectangular, with widths of 200 mm and depths ranging from 400 mm to 750 mm. The first floor had a cast-in-situ concrete slab, the second floor had prestressed solid planks, except for the toilets, which were cast-in-place concrete slab, and the roof was a cast-in-place concrete slab. The stair and gable roof structures were steel, and the floor-to-floor height was 3.5 meters.

When switching to prefabricated construction, all structures were prefabricated. The engineering team had to redesign the entire building structure. Figure 2 illustrates the overall prefabricated structure of the building. The piles were made of prestressed concrete, and the footings were precast concrete. The columns were transformed into precast concrete wall-bearings with thicknesses of 100 mm and 150 mm, making the structural walls thinner than the original columns by 50 mm or 100 mm, resulting in wider interior spaces. However, the size of exterior openings (doors and windows) had to be narrower due to the limitations of precast concrete walls, which must have a border of 200 mm to 350 mm (see Figure 3). The round columns that supported the parking roof were changed to steel columns. Additionally, the floor-to-floor height of the entire building had to be changed to 3.40 meters (see Figure 3) as the transportation limit for precast concrete walls is 3.40 meters and walls higher than this can obstruct public electrical wires during transport. Therefore, the steel stairs had to be changed in height and redesigned. The floors were changed to precast concrete floors placed on top of the precast concrete walls. The floor structure of the first floor was made of hollow core slabs, and the second floor was a large precast concrete floor, similar in size to the precast concrete walls. Precast concrete beams were placed on the footings to support the floor and walls at the first level. At the second level, beams were placed in areas where there were no walls to support the floors, such as in the double volume living room and stair hall (see Figure 4). The concrete roof slab in the stair hall was changed to a lean-to roof hidden behind the wall (see Figure 5). The concrete roof slabs around the building were also changed to lean-to roofs. The gable roofs remained steel structures, but the engineer had to redesign the connection between the roof structure and precast concrete walls.

**Figure 2**

*The Overall Prefabricated Structure of the Building*

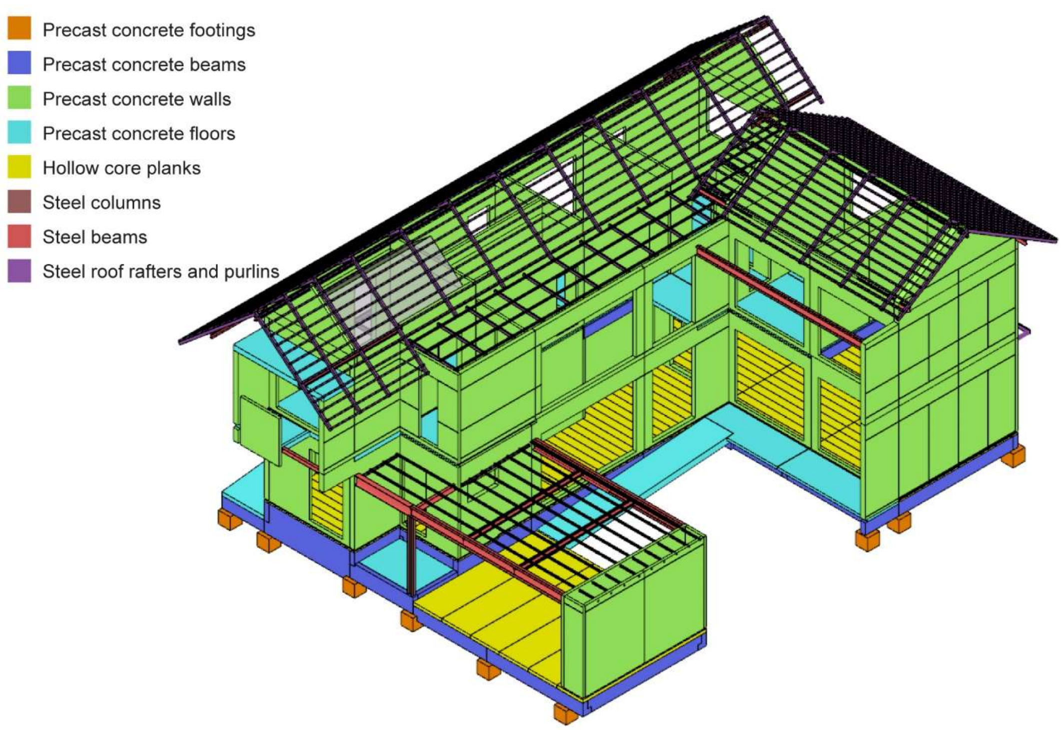


**Figure 3**

*Precast Concrete Walls Must Have a Border of 200 mm to 350 mm*

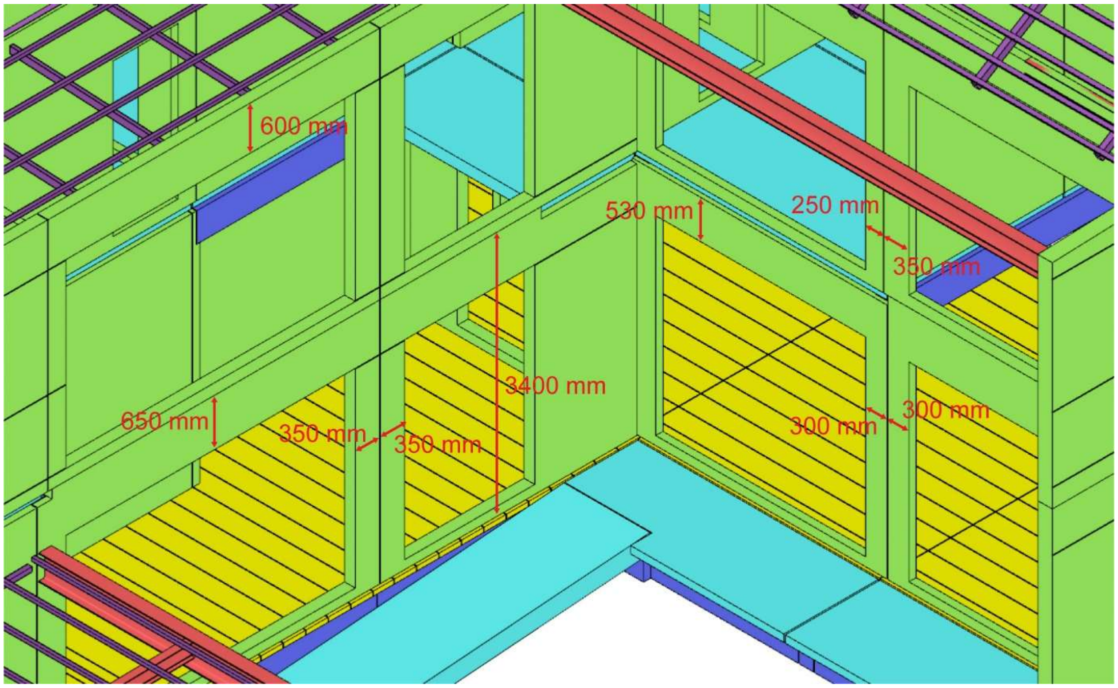



**Figure 4**

*The Beams That Support the Second Level's Floor*

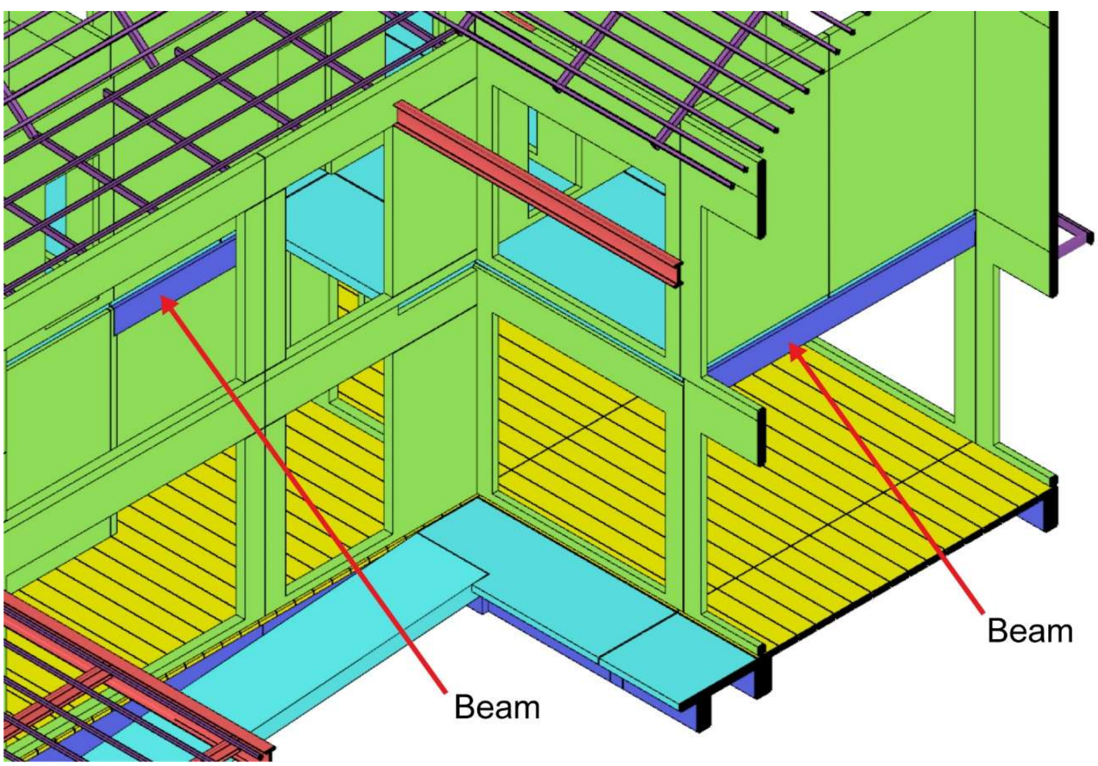


**Figure 5**

*The Concrete Roof Slab in the Stair Hall (a) and the modified Lean-to Roof Hidden Behind the Wall (b)*


(a) (b)

### Architectural Considerations

Some architectural designs had to be altered due to the changes in the building's structure. One of the major changes that impacted the architectural design was the floor-to-floor height. The architect, along with the interior architect, worked closely with the structural engineering team to address the challenges introduced by the new load-bearing precast concrete walls. This collaboration led to a series of revisions being implemented, resulting in adjustments such as reduction of the stair slope and revision of riser dimensions. Additionally, the ceiling elevation had to be lowered, which, consequently, influenced the dimensions of the aluminum doors and windows. The width of the aluminum doors and windows had to be made narrower due to the constraints of the precast concrete walls (see Figure 6).

In the original design, all walls were brick masonry with plaster layers on both sides. However, with the new load-bearing wall structure, the brick masonry walls were replaced by precast concrete walls. The plaster layers were no longer necessary due to the smooth surface of the precast concrete walls. The joints between precast concrete wall panels also impacted the architectural appearance, so the architect had to work with the engineering team to divide the precast concrete wall into suitable sections. Some wall panels were designed with wall reveals to blend in with the joints between wall panels (see Figure 7).

The conversion of concrete roof slabs to lean-to roofs also had an impact on the architectural appearance. The architect had to redesign details such as the edges of the roofs and the roof thickness.

Furthermore, the new load-bearing wall structure removed the need for columns in the rooms, resulting in wider interior spaces. Some rooms, such as the bathrooms and kitchen, became wider. As a result, the design of the bathroom counter basins and the kitchen counter had to be modified.

### Mechanical, Electrical, and Plumbing Challenges

Unlike the traditional on-site construction method where MEP systems can be installed and modified at any time during the construction process, the MEP systems in prefabricated construction have to be coordinated and installed in the factory. To ensure a seamless integration of these MEP systems with the precast concrete elements, collaboration between the contractor's engineering team and the architectural team was critical. In this effort, the architectural team took on a pivotal role by providing the precise positioning of MEP fixtures within the architectural design. This detailed information served as a foundational guide for the contractor's engineering team, enabling them to effectively plan and integrate the MEP systems into the precast concrete elements at the factory level. This synchronized collaboration between the architectural and engineering teams was instrumental in optimizing the prefabricated construction process, leading to a more cohesive and efficient integration of building systems.

As for the electrical system, the architect had to identify the positions of all lighting switches and power outlets, including the height from floors and the distance from corners. Furthermore, the conduits and the electrical boxes that were embedded in the precast concrete, and had to be planned for in the shop drawings. The position of the electrical shaft also had to be identified on the precast concrete floor slab.

**Figure 6**

*Examples of the Width and Height of the Aluminum Doors Before (a) and After the Revision (b)*

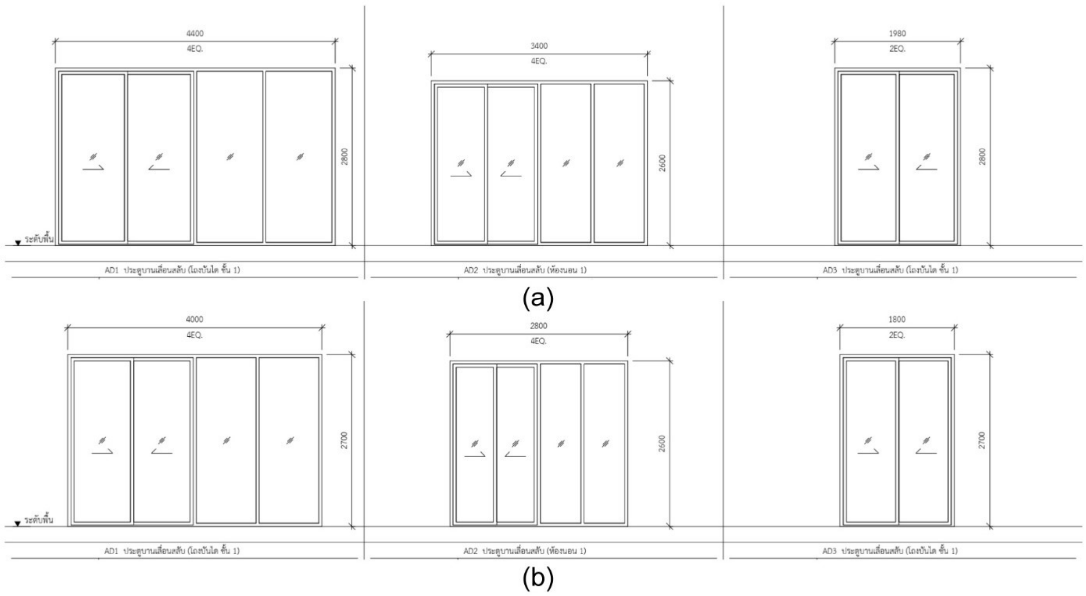



**Figure 7**

*Examples of Wall Reveals and Joints Between Wall Panels*

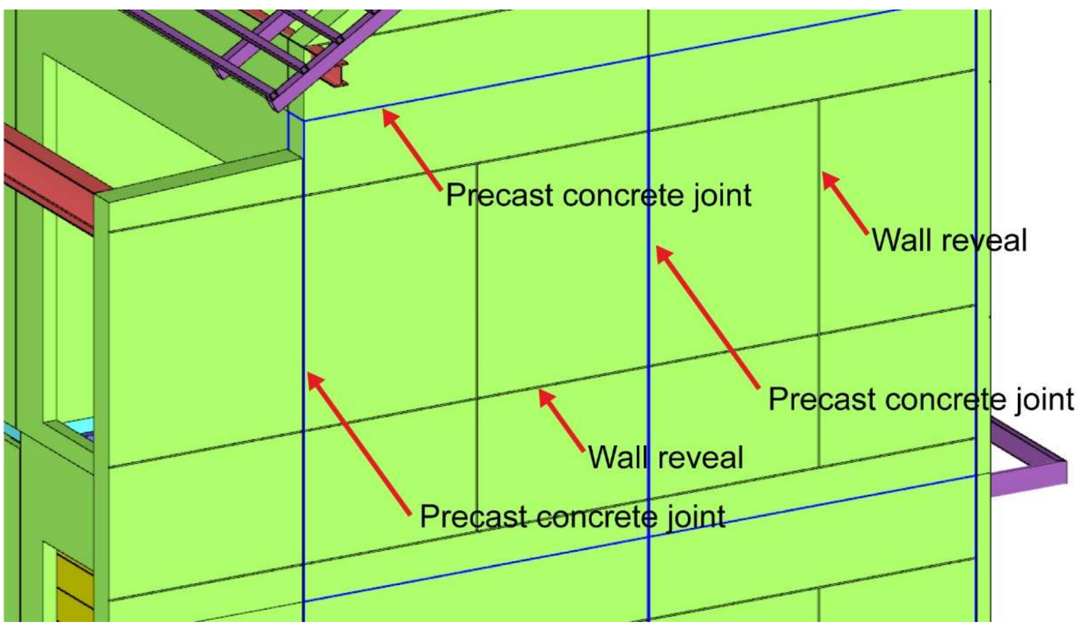


**Figure 8**

*The Electrical Boxes Embedded Inside the Precast Concrete Walls*

The mechanical systems in this building comprised the air-conditioning system and exhaust fan system. The air-conditioning system required pipes embedded inside and which penetrated the precast concrete walls, and the exhaust fan system required air hoses to penetrate the precast concrete walls. Therefore, the location and size of all the pipes and air hoses had to be planned and coordinated with the architect and the contractor's engineering team in the shop drawings to avoid any conflicts with the architectural and structural designs.

The plumbing systems in the building consist of water supply and drainage systems. To ensure they would not interfere with the other building systems, design of the water supply and drainage systems needed to be coordinated with the architectural and structural design engineers. The pipes for the water supply system had to be embedded inside the precast concrete walls, while the pipes for the drainage system had to penetrate the precast concrete floors. Moreover, the positions of the plumbing shafts and sewer pipes had to be identified and planned in the shop drawings, while the positions of plumbing fixtures such as faucets, taps, sinks, toilets, and bathtubs also had to be determined and coordinated with the architectural design.

Table 1 summarizes the changes made to different aspects of the design when converting from the post and lintel structure to the precast concrete wall-bearing structure. The structural, architectural, and MEP aspects are outlined, along with the specific modifications that were implemented to address the challenges of the conversion.

**Table 1**

*Changes in Design Aspects for Conversion from Post and Lintel to Precast Concrete Wall-Bearing Structure*

| Aspect | Original design | New design | Changes |
|---|---|---|---|
| Structural | Post and lintel (framed) system, cast-in-place RC | Wall-bearing system, precast concrete | • Piles: Prestressed concrete<br>• Footings: Precast concrete<br>• Columns: Precast concrete wall-bearings<br>• Exterior openings: Narrower due to precast concrete limitations<br>• Floor-to-floor height: 3.40 meters<br>• Steel stairs: Adjusted height and design<br>• Floors: Precast concrete<<br>• Beams: Precast concrete on footings<br>• Roofs: Converted to lean-to roofs |
| Architectural | Original design by the architects | Adjustments in designs due to structural changes | • Stairs: Reduced slope, revised risers<br>• Ceiling: Lowered, affecting doors and windows<br>• Walls: Precast concrete replaced masonry, no plaster<br>• Divided walls with reveals<br>• Roof: Conversion to lean-to roofs<br>• Interior spaces: Wider due to load-bearing walls<br>• Room designs: Modified (e.g., wider bathrooms, kitchen counters) |
| MEP | On-site installation and modification | Factory coordination for installation | • Collaboration between teams for MEP integration<br>• Positioning of switches, outlets, conduits, boxes, shafts<br>• Air-conditioning and exhaust: Pipes and hoses in precast walls<br>• Plumbing: Coordinated with architectural and structural design |

# DISCUSSION

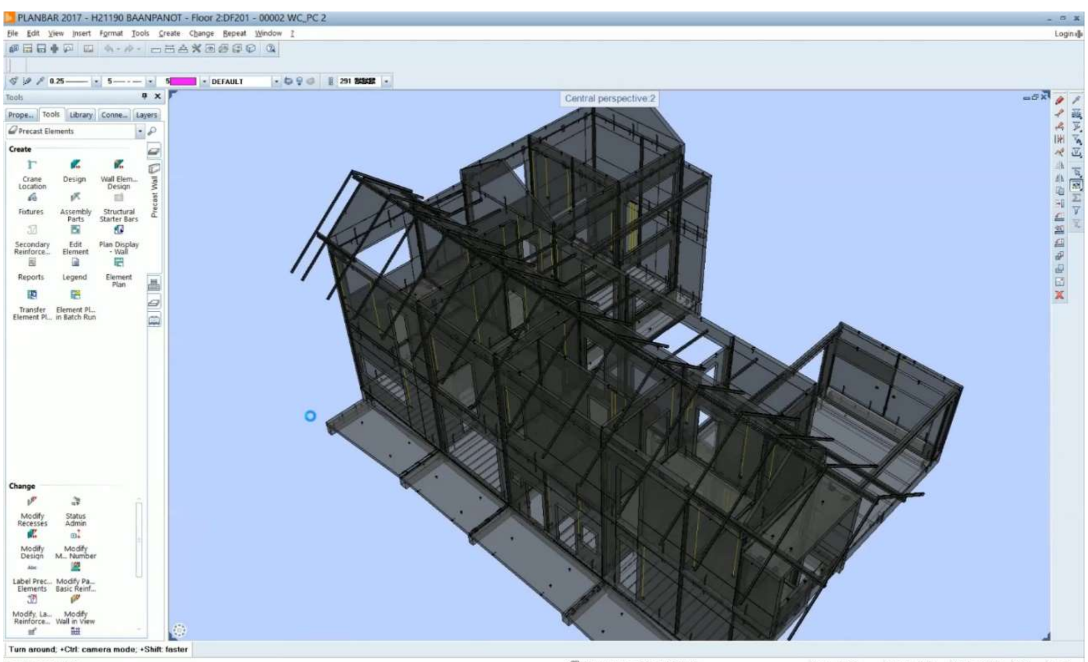
## The Role of BIM in Overcoming Challenges

As mentioned in the previous section, the conversion process was a challenging task that required significant effort, coordination, and planning. BIM was used to address structural, architectural, and MEP challenges, ensuring that the design and construction process was efficient, effective, and successful. Construction project coordination through BIM was found to be one of the most important factors for successful BIM adoption and implementation, as it facilitated a streamlined and coordinated workflow (Liu et al., 2022). Furthermore, the use of BIM was found to be effective in improving the efficiency and rapidity of the prefabricated design process (Wasim & Oliveira, 2022).

Regarding the structural issues, the engineering team utilized BIM to overcome these challenges in the conversion process by visualizing the new structure and providing accurate data and simulations to test the design changes. The team utilized PLANBAR (Allplan, 2023), a BIM-based precast detailing software based on the Allplan platform that was developed by the Nemetschek company. Allplan provides architecture, engineering, and construction professionals with tools to design, model, and visualize building projects. PLANBAR is integrated into the workflow by importing the Revit model into PLANBAR, and then using it as the initial basis for the structural conversion. This allows for comprehensive assessment of the existing design elements and clear understanding of the scope of changes required. For this project, the engineering team employed PLANBAR's features to model the new precast concrete components, including the rebar, inside the concrete structures. This modeling process encompassed designing precast concrete walls, foundations, beams, and other structural elements essential for the wall-bearing system. Moreover, PLANBAR's visualization capabilities played a pivotal role in communicating the redesigned structural elements to the entire project team. This visual representation aided in effectively conveying complex design changes and fostering collaborative decision-making. Figure 9 shows the overall structural BIM model that was created in PLANBAR.

**Figure 9**

*The Structural BIM Model Created in PLANBAR*



With regards to architectural considerations, the architectural model of the building was created using Autodesk Revit. This architectural BIM model was created prior to the structural conversion. After the engineering team had created the structural model using PLANBAR, the architectural team utilized the structural model to review and make adjustments to the architectural model in Autodesk Revit. This ensured that the architectural design was integrated seamlessly with the structural and MEP systems. Through the BIM model, the impact of design changes on the building's overall aesthetic appearance could be easily visualized. Figure 10 displays the architectural BIM model before and after editing for the structural changes. Slight differences can be noticed, such as the size of the aluminum doors and windows, the edges of the parking roofs, the overflow on the roof's parapet, and the column at the entrance.

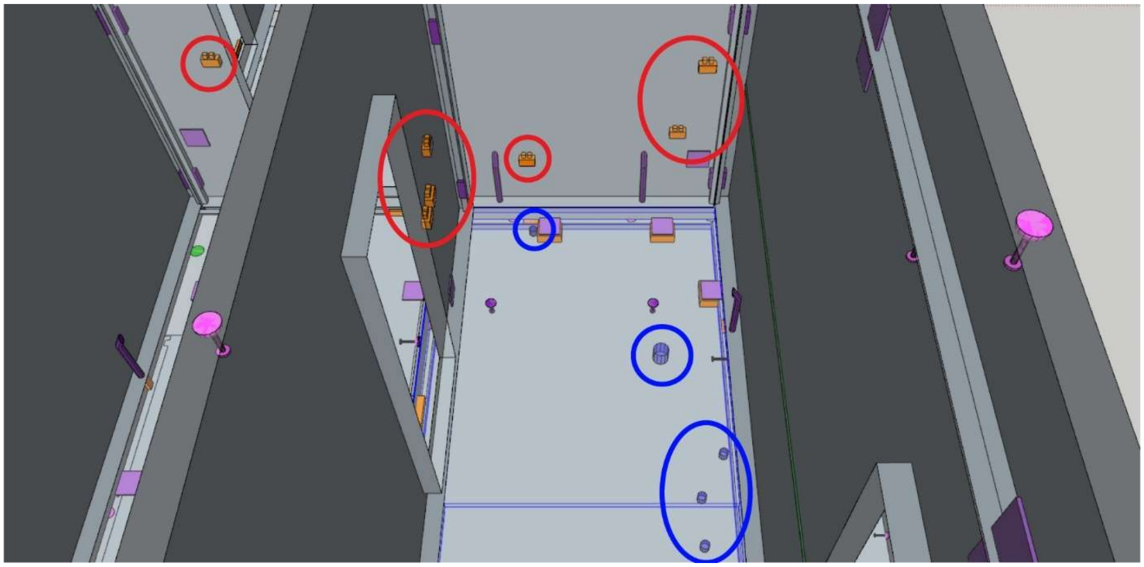
Regarding MEP challenges, BIM was used to coordinate the MEP systems and ensure their integration with the architectural and structural design. The engineering team utilized PLANBAR to create a shop drawing of the precast concrete structure. All components, including the electrical system's conduits and electrical boxes, the air-conditioning system's pipes, and the plumbing system's water supply pipes that were embedded in the precast concrete wall, were modeled in BIM and sent for manufacturing at the factory. Figure 11 illustrates the electrical boxes and plumbing system’s pipes modeled in the BIM.

**Figure 10**

*The Architectural BIM Model Before (a) and After (b) Editing for the Structural Changes*


**Figure 11**

*The Electrical Boxes (Red Circled) and Plumbing System’s Pipes (Blue Circled) Modeled in the BIM*



In summary, the conversion process of this building project presented several challenges that required the coordination of different teams. BIM technology was an indispensable tool in this process, providing efficient and effective ways to address structural, architectural, and MEP challenges. By using BIM software like Autodesk Revit and PLANBAR, the different teams were able to collaborate on and visualize the design, allowing them to make adjustments in real time to ensue that the final product was of high quality and met the desired aesthetic and functional requirements. Furthermore, it's important to note that the conversion process using BIM technology took approximately one month to complete. This timeline encompassed the intricate tasks of structural design, architectural adjustments, and MEP considerations, all seamlessly integrated through the collaborative capabilities of BIM tools.

## Construction Phase

The construction of the building began in September 2021 and ended in February 2023, taking a total of 17 months, including the interior decoration. Installation of the precast concrete structure took one month at the construction site; another month was required to complete the stair and roof structures. The remaining 15 months were devoted to the architectural and interior details.

Implementing BIM into this conversion process yielded significant benefits. BIM played a crucial role in minimizing potential mistakes and conflicts among various project aspects. Specifically, the structural BIM model was employed to guide the fabrication of precast concrete elements, resulting in improved accuracy and a more streamlined construction process. However, it is important to note that the impact of BIM on construction time cannot be determined due to the absence of a conventional construction plan for comparison. Additionally, the allocation of 15 months for architectural and interior detailing might raise questions about the differing timeframes for architectural and structural work. The timeline allocated to architectural work is influenced by a range of factors; for example, the complexities of interior design, involving intricate details, choices, and finishes, often contribute to the extended duration. Furthermore, the labor shortages brought about by the COVID-19 pandemic also affected construction progress, contributing to longer timelines.

Figure 12 illustrates the construction phase of the case study. The precast concrete foundation, which included piles, footings, and ground beams, was installed first, as shown in Figure 12a. The precast concrete floors and walls were then put in place level by level, as depicted in Figure 12b. The steel roof structure and roof tiles were installed after all precast concrete components were in place, as shown in Figure 12c. Finally, the architectural elements such as doors, windows, and architectural finishes were added to complete the construction, as shown in Figure 12d.

During the construction phase, BIM was utilized to track changes and resolve any arising issues, providing benefits such as reducing the number of errors, enhancing communication, and ensuring that the final product met the project's aesthetic and functional requirements. The use of BIM technology during the construction phase was a crucial factor in ensuring the success of this building project.

**Figure 12**

*The Construction Phase of the Case study, From Start to Finish*


# CONCLUSION

In conclusion, this case study highlights the challenges encountered in the conversion of a post and lintel structure to a precast concrete structure in a real building construction project. The case study presented in this paper is a 2-story house with a total area of 316 square meters. The house was designed by the architect using Autodesk Revit 2021, and was initially intended to be a post and lintel structure. However, the owner decided to use a precast concrete structure instead, following the suggestion of the contractor. The switch to precast concrete was made due to the advantages it offered, such as faster construction times, improved quality and consistency, and cost-effectiveness.

Switching from one type of structure to another can be a challenging task that requires significant effort, coordination, and planning. The challenges were divided into three building systems: the structural system, the architectural system, and the MEP system. The structural system challenges were in the form of a complete redesign. The architectural system created challenges in terms of floor-to-floor height, door and window width, and architectural details that affected the aesthetics of the building, such as the edges of the roofs and the joint design between wall panels. The MEP system challenges primarily involved coordinating design and installation with the factory. The conversion process required close collaboration between the contractor's engineering team and the architectural team to ensure the building systems were integrated and suitable for the design.

The case study highlights the significance of using BIM in overcoming the challenges that arise in construction projects. The use of BIM software like Autodesk Revit and PLANBAR enabled seamless collaboration between different teams and allowed for real-time visualization and adjustments to the design, leading to a final product of exceptional quality that satisfied both aesthetic and functional needs. This case study demonstrates the benefits of utilizing BIM technology, including increased efficiency, improved quality, and effective collaboration, in building construction projects. By learning from the experiences shared in this case study, professionals dealing with similar situations can gain practical insights.

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