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ORIGINAL CONTRIBUTION

BIM in Precast Construction: A Case Study of Highrise Residential Building

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Abstract— **The study objectives are to analyze BIM application in the project practice and evaluate different implementation influence during the construction period. Building Information Modelling (BIM) combines various building information data in the model. It has a series of characteristics of visualization, coordination, simulation, optimization, and others. For the whole life cycle of building, BIM has prominent advantages in project management and operation management. The main research method is the case study for this paper. The case Forest City project reported BIM application on a typical high-rise condominium project in Malaysia. Two precast residential buildings executed the BIM tool for construction management. The participants tried to use the entire construction process simulation. They intend to obtain the best management method to improve their work efficiency and reduce project cost. From the Forest City project case study, the designers and engineers provided various precast components 3D presentation. It reduced rework through BIM clash detection. Main-con QS took off this project quantity accurately through the BIM platform. BIM technology helped relevant participants to improve work efficiency. The research implications are displayed a useful technology for precast construction management, such as BIM 3D/4D/5D functions.**

Index Terms— **Building Information Modelling, BIM, Construction Industry, Precast Building, Construction Project Management**

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I. INTRODUCTION

BIM technology is a kind of digital design tool which is applied in engineering construction management. It integrates various information about the project as a parameter model. It could be applied in the building whole life cycle process, including project planning, construction management, operation and maintenance, and the others. The conventional precast construction management instruments include Auto CAD (for layout/section/elevation drawing), Micro project (for work schedule), Glodon software (for quantity survey) and the others. But most of construction information are separated. The BIM tool (such as Revit software) combines many kinds of building information in one platform together. The modern precast project needs to exploit this technology to reduce construction progress and cost [1, 2].

The application of BIM technology is helping to solve the problem of poor communication between various stages and different participants. BIM platform provides the database of collaborative work. Reizgevičius, et al. [3] presented BIM have profound impact on the sustainability construction industry. Normally, BIM technology has may applications in construction industry, such as visualization model, construction simulation, clash detection, take-off quantity, work schedule management and the others. Through a series of literature reviews and case study, it shows that BIM technology has been gradually maturing in construction project management. This study aims to analyze BIM application in a high-rise residential precast building project, including evaluation of 3D model design, clash detection, cost management, precast components supply, work schedule management, Quick Respond (QR) code.

II. METHODOLOGY

The main research method of this article is using reference papers through Google scholar and other resources. More than 60 relative studies were retrieved by the Google search engine online system. The main keywords include BIM application, BIM technology, precast construction, project management, and others. Many research papers introduced the application of BIM technology in engineering management. Sanhudo et al. [4] explored the BIM practice in the industrialized high-rise building also. There are 12 researcher's opinions cited for this study.

The second research method is a real case study including two blocks of precast high-rise residential building. This project name is Forest City plot 26 which is in the south of Malaysia. The main contractor is the Giant Leaf Construction company, which has come from China. The block C2 and block C4 height are 124.4 meters with 40 storey (including 2 storey car park). The original structure work schedule is 549 days (from project schedule). These two building each level precast components data as below Fig. 1:

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Summary of precast component every storey

Block	Vertical precast component amounts	Horizon precast component amounts	Max weight
C2	185 pcs	139 pcs	7.67 ton
C4	135 pcs	107 pcs	4.04 ton

Fig. 1. Precast building components

This case study shows some work performances during project management. The BIM technology provided new techniques for high-rise residential building construction works. This research brings the experiences to improve the high-rise condominium construction work efficiency.

III. THE BIM APPLICATION IN PRECAST BUILDING

A. The BIM 3D Visualization Design Application

The traditional 3D visual design tool includes 3Dmax, SketchUp, and the other software. Normally, most of the software caused some communication gap between the designers. Because the software function limitations bring considerable information gap between the conventional 3D drawing and real design. Furthermore, there is a large amount of design work should be expressed by the traditional AUTO CAD platform, such as layout, section, elevation, detail drawing and the others. Qin [5] presented that BIM technology changes the 2D drawing into 3D model and make the traditional design work more scientific and sophisticated.

Due to the traditional 2D drawing needs very high requirements for understanding, the common construction workers cannot get the information accurately. It leads to reduce work efficiency. As a revolutionary technology, BIM provides innovative collaboration through 3D modeling [6].

The normal 3D design tool depth is not very strong, and the software operation is too complicated also. The fragmentation information is easy to make mistakes and wastes more time to understand. However, BIM technology brings some advantages. BIM technology is not only a 3D visualization tool but also provides various construction information. It is helpful to make the owner and engineer really to get rid of technical barriers. For example, the site layout displays the Tower Crane 1 coverage is purple area and Tower Crane 2 coverage is red area. The Giant Leaf company engineers use BIM make the model as below Fig. 2 :

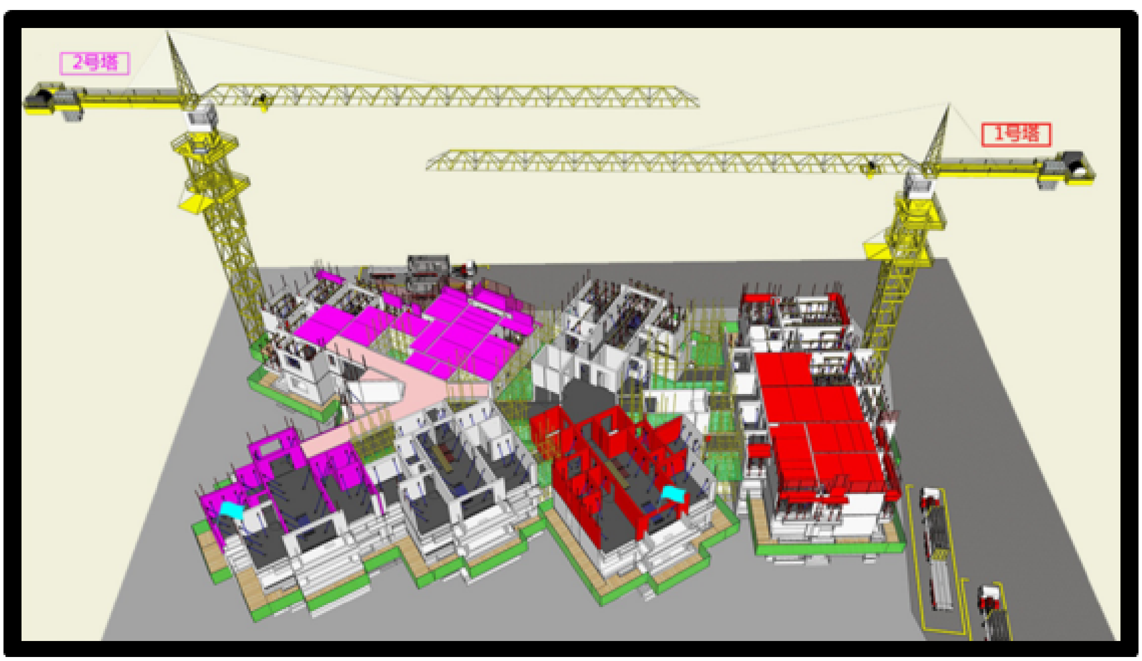


Fig. 2. BIM for site layout

Through the Revit software of BIM, the precast building designer can make precast components visually, such as facade, balcony, plant box, staircase, house shelter, and the others. The precast wall and precast balcony 3D model as below Fig. 3 (a & b):

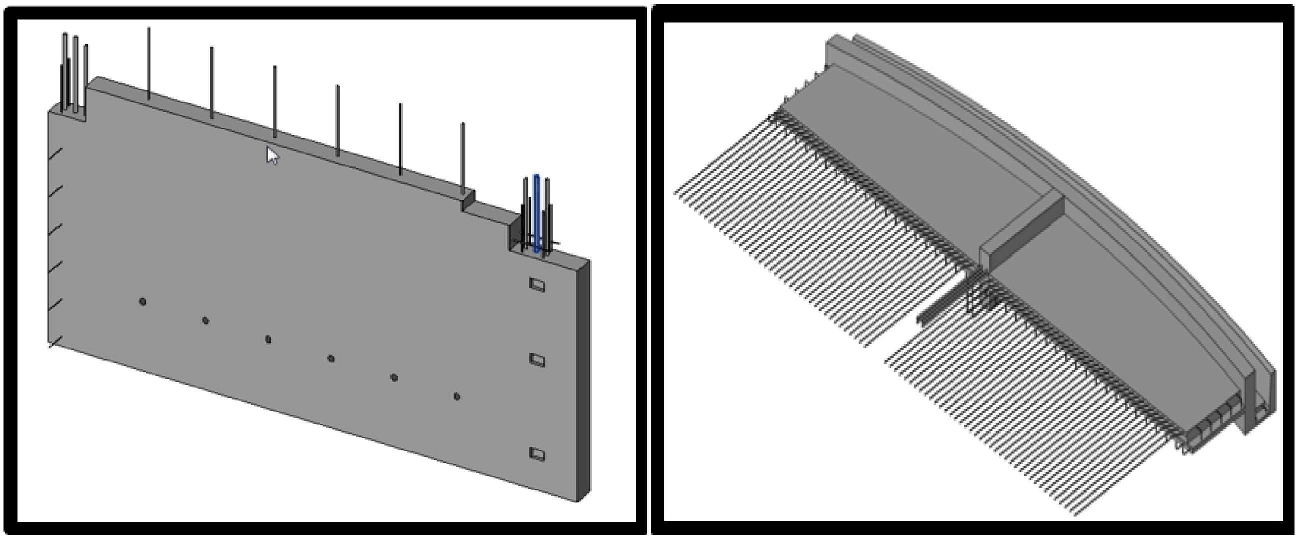


Fig. 3. (a) BIM for precast wall (b) BIM for precast balcony

B. The Application of Clash Detection

Many hidden design errors caused by conventional design tools. The designers need to waste more time to verify the drawings. Such as common clash problems are emerged with intricate pipelines and electrical routes. For the precast building, it is built with thousands of precast components. Some of the connections between different products are easy to appear the clash issues, including the start rebar fighting problem. These issues often lead to re-assembly work. Furthermore, these phenomenons cause construction progress delay problems.

The BIM designer tried to simulate the position of accessory parts in this case study. Then the designer carried out clash detection to correct the wrong design. The BIM tool reduces the overlapping error and improves construction work efficiency [7]. For example, this project main contractor Giant Leaf Construction engineers used BIM technology to inspect clash issues as below Fig. 4 (a & b):

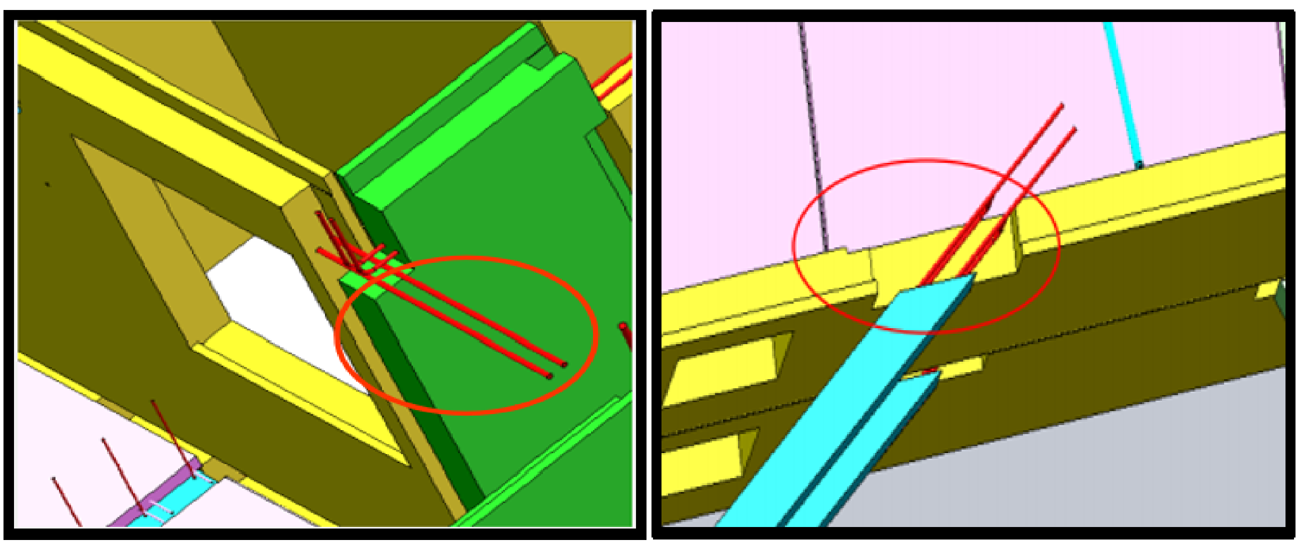


Fig. 4. (a) BIM clash detection for wall (b) BIM clash detection for beam

Jowett et al. [8] analyzed of clash detection of BIM technology and presented it is useful to reduce the construction cost and achieve progress goal. The BIM has itself advantage to simulate actual result and optimize the design work. In this case study, BIM application can improve precast building design accuracy and enhance project management also.

C. The Application of Construction Process Simulation

As modern building development, construction projects become more complex gradually. The construction engineers have to face a lot of completed drawings and specifications. So, it needs engineers to carry out the construction work efficiently. The experiments showed that BIM has a good application future [9]. Comparison with the traditional tools and BIM technology, BIM can simulate and guide the construction progress through its visualization function. Especially, it has great practical value in the precast building project management.

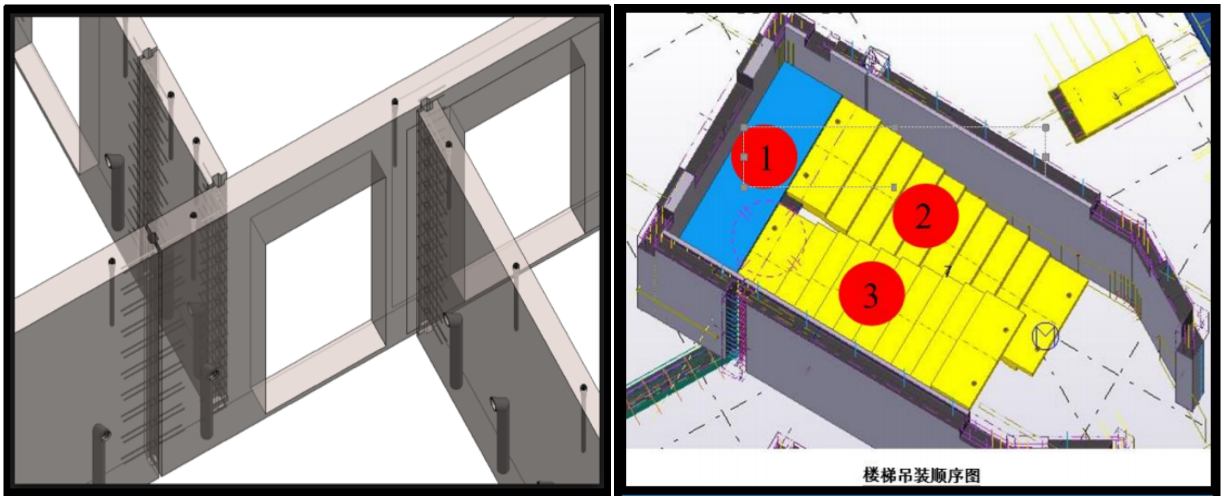


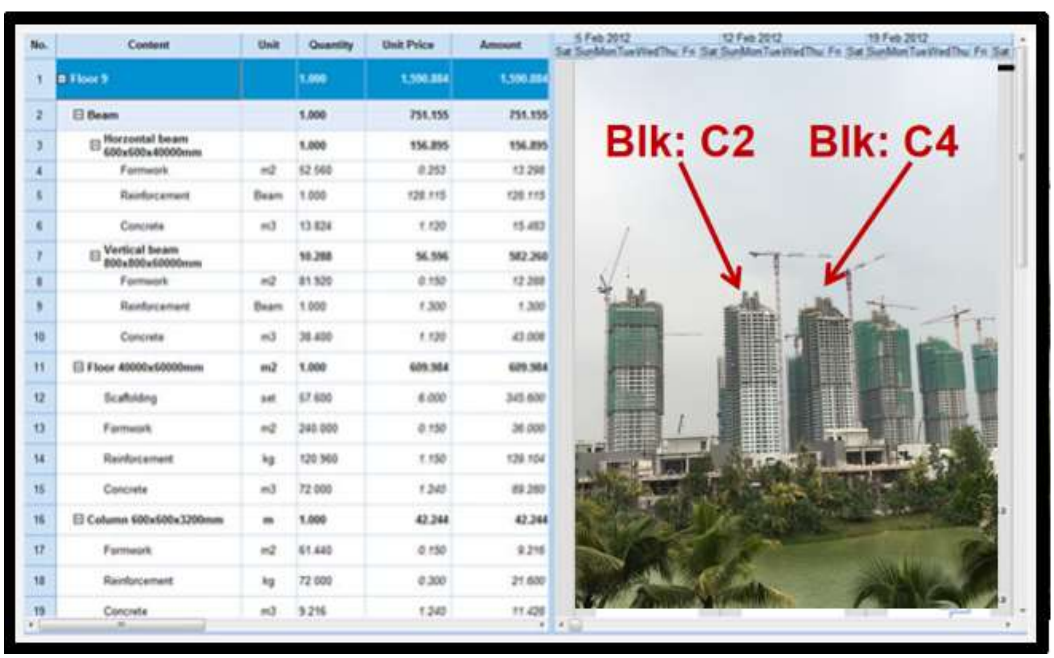
Fig. 5. (a) Partition installation simulation (b) Staircase installation sequence

The Forest City plot 26 project C2 and C4 are two high-rise precast buildings. The installation sequence is an important work for this project because it needs to install more than thousands of precast components. It includes loading, installing, supporting, grouting, and other work. The BIM simulation reflects each component installation relationship visually, such as above Fig. 5 (a & b). This project engineers use BIM technology to simulate all kinds of situation which would happen in the construction site. It is further to assist construction project management efficiency.

D. The Application of Quantity Take-off

The construction project Quantity Surveyor (QS) work is a large workload task. Sometimes, the conventional calculation method is difficult to meet the project cost management requirement. Through the BIM tool, the QS can quickly and accurately get the material amount. The BIM 5D application is easy to get a summary of. The QS adopted the BIM tool to take-off each precast component material amount easily, such as the rebar, formwork, concrete, window, door and the others. It saves more calculation time and improves work accuracy.

Pilyay and Shilova [10] expressed BIM 5D calculation is useful to control the project cost. The BIM tool provides a quantity amount quickly and reduces the precast component calculation errors. In this Forest City plot 26 projects, the engineers used BIM 5D to take-off precast component's concrete volume and weight clearly as below Fig. 6.



No.	Content	Unit	Quantity	Unit Price	Amount
1	Floor 9		1.000	1,590.884	1,590.884
2	Beam		1.000	751.155	751.155
3	Horizontal beam 600x600x40000mm		1.000	156.895	156.895
4	Formwork	m2	52.560	0.253	13.298
5	Reinforcement	Beam	1.000	128.115	128.115
6	Concrete	m3	13.824	1.120	15.483
7	Vertical beam 800x800x60000mm		10.288	56.596	582.260
8	Formwork	m2	81.920	0.150	12.288
9	Reinforcement	Beam	1.000	1.300	1.300
10	Concrete	m3	38.400	1.120	43.008
11	Floor 40000x60000mm	m2	1.000	609.984	609.984
12	Scaffolding	set	57.600	6.000	345.600
13	Formwork	m2	240.000	0.150	36.000
14	Reinforcement	kg	120.960	1.150	139.104
15	Concrete	m3	72.000	1.240	89.280
16	Column 600x600x3200mm	m	1.000	42.244	42.244
17	Formwork	m2	61.440	0.150	9.216
18	Reinforcement	kg	72.000	0.300	21.600
19	Concrete	m3	9.216	1.240	11.428

Fig. 6. Take-off precast components quantity

E. The Construction Work Schedule Management

Mirzaei, et al. [11] researched 4D-BIM dynamic clash detection to identify time–space conflict and quantify their impact on construction project management. From a traditional view, the construction progress is generally presented according to project work schedule and the site photos. But this method is lack of intuitive effect. It needs more 3D imagine ability to compare the plan progress with the actual progress.

Through BIM technology application, this Forest City plot 26 project main contractor established a 4D model and linked with construction process. The BIM 3D+1D (3D+time) function kept the consistency of the model and work time. They imported work date into the BIM model. Under the virtual reality environment, they simulated the entire precast building construction process. It is helping them to optimize construction progress previous. They adjusted this project work schedule, including each precast component installation time, including beam, slab, column, lift wall, and staircase and the others.

Furthermore, the construction work schedule can be directly and quickly compared with the actual progress at any time through the BIM tool. It is useful for project participants monitor the problems which hinder project construction progress. BIM technology accelerates feedback construction progress management.

F. The Application of QR Code

Nowadays, the BIM technology integrates QR code to connect project site information and BIM platform database. By scanning the QR code, the user gets relevant information rapidly, such as precast component width, height, thickness, and other information. In this Forest City plot 26 projects, the engineers got relative documents, videos, and other information quickly through the QR code. For example, this project technical engineer made the method statement QR code as below Fig. 7:

Fig. 7. QR code for method statement

The Forest City plot 26 two-block buildings have about 21,660 pcs precast components. The QC need inspect the construction quality strictly. In fact, the QC can take every precast component information easily, because each precast product has the sticker of unique QR code from the precast manufacturer. Everyone can quickly verify this precast product produced date, property, and other information. In the future, the Forest City developer and the main contractor plan to exploit the RFID technology more and apply it in the next stage. By scanning the QR code, participants can track construction process steps anytime anywhere. Iacovidou, et al. [12] expressed that construction project management could be enhanced through the RFID application.

IV. DISCUSSION AND CONCLUSION

Based on the characteristics of the BIM tool, it has been widely used in the construction industry. This technology has applied various construction activities, including project design, 3D presentation, cost management, construction simulation, operation and maintenance, and the others. The BIM functions are permeated into the whole life cycle of the building project. BIM technology has been constantly studied and explored including precast high-rise buildings.

From the Forest City project case study, the designers and engineers provided various precast components 3D presentation. It reduced rework through BIM clash detection. During the construction, the main contractor Giant Leaf Construction extended BIM form 3D model to 4D (time) and 5D (cost) model. The site engineer made the precast components installation simulation and strengthened the work schedule management. Main-con QS took off this project quantity accurately through BIM platform. BIM technology helped relevant participants to improve work efficiency. Furthermore, this project manufacturer provided each product's QR code for this project. It is helpful for QC work.

Bhatti et al. [13] showed that BIM application in the last years has got many successful implementations, such as in the United States, United Kingdom, Germany, and the other developed countries. In the future, BIM will be developed more based on computing cloud model. It needs more research and exploits from now on. The construction project participants apply BIM 3D/4D/5D/6D functions more easily.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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