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Innovation of Prefabrication Construction Methods for Cost and Time Efficiency in The High Rise Building Project of Perum Perumnas

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Abstract

Prefabrication has been widely used in construction projects. Prefabrication improves construction speed, architectural quality, material efficiency, and worker safety while limiting construction's environmental impact than conventional construction practices built on site. This research explains the advantages of prefabricated construction methods and offers an alternative method for innovation for the High Rise Building Project of Perum Perumnas. The prefabrication method is an alternative solution based on the SWOT analysis, and software for modeling and structural design is STAAD.Pro V8.I by Bentley System, inc. The research results have shown that prefabrication methods in the High Rise Building Project of Perum Perumnas can save 7% (deviation = 868.47 million) more than the current construction method (conventional). In terms of time, the prefabrication method is faster than traditional methods, with a time difference of 371 days. The estimated time required to complete upper structure work using conventional methods is 557 days. In comparison, the time needed to complete upper structure work with prefabricated methods is only 186 days, assuming the working time is eight hours per day. And the risk analysis is generally mentioned. Therefore, based on the calculation results, it can be concluded that the prefabrication method can increase the number and quality of development production in the High Rise Building Project of Perum Perumnas.

Keywords: *Prefabrication, cost, high rise building, STAAD Pro*

Abstrak

Prefabrikasi telah banyak digunakan dalam proyek konstruksi. Prefabrikasi meningkatkan kecepatan konstruksi, kualitas arsitektur, efisiensi material, dan keselamatan pekerja serta membatasi dampak lingkungan konstruksi dibandingkan dengan praktik konstruksi konvensional yang dibangun di lokasi. Penelitian ini menjelaskan keunggulan metode konstruksi prefabrikasi dan menawarkan metode alternatif untuk inovasi Proyek Gedung Tinggi Perum Perumnas. Metode prefabrikasi adalah solusi alternatif berdasarkan analisis SWOT, dan perangkat lunak untuk pemodelan dan desain struktural adalah STAAD.Pro V8.I oleh Bentley System, inc. Hasil penelitian menunjukkan bahwa metode prefabrikasi pada Proyek Gedung Tinggi Perum Perumnas dapat menghemat 7% (deviasi = 868,47 juta) lebih dari metode konstruksi saat ini (konvensional). Dari segi waktu, metode prefabrikasi lebih cepat dibandingkan dengan metode konvensional, dengan selisih waktu 371 hari. Estimasi waktu yang dibutuhkan untuk menyelesaikan pekerjaan struktur atas dengan metode konvensional adalah 557 hari. Sebagai perbandingan, waktu yang dibutuhkan untuk menyelesaikan pekerjaan struktur atas dengan metode prefabrikasi hanya 186 hari, dengan asumsi waktu kerja delapan jam per hari, dan analisis risiko secara umum. Oleh karena itu, berdasarkan hasil perhitungan dapat disimpulkan bahwa metode prefabrikasi dapat meningkatkan jumlah dan kualitas produksi pembangunan pada Proyek High Rise Building Perum Perumnas.

Kata kunci: *Prefabrikasi, biaya, gedung bertingkat, STAAD Pro*

Introduction

Prefabrication construction is a process carried out in a factory where building components are transported to the construction site for installation (*Home - IBUILT*, n.d.). Previous research has found that prefabrication is a production strategy with the following advantages: environmentally friendly energy savings and waste reduction (Hong et al., 2016) reduce project duration, increase productivity, reduce labor requirements and costs, and positively impact supply chain problems allowed (Vanegas et al., 2002), improve worker safety through reduced exposure to bad weather, extreme temperatures, and hazards operations. To summarize, prefabrication improves construction speed, architectural quality, material efficiency, and worker safety while limiting the environmental impact of construction compared to conventional. Construction practices are built on-site (Boafo et al., 2016). It is expected to solve the affordable housing crisis by delivering fast housing at a lower price (Thompson, 2019). Mass affordable housing construction is relevant because, economically, modern industrial construction methods are based on standardization, integration, and typification (Generalova et al., 2016).

Prefabrication has excellent potential to surpass conventional processes in many aspects. Nevertheless, prefabrication is not a cure-all solution that automatically ensures shortened construction time, lower construction costs, and other benefits (Lu et al., 2018). Projects involve several people related to each other, activities, and the main sponsor is usually interested in ineffective use of resources to complete the project efficiently and on time. Projects have specific goals and are in the process of achieving those goals. There are three constraints obstacles that must be faced. The three obstacles are effort achievement of goals based on quality, time, and cost (*Open Library - Manajemen Proyek*, n.d.). This study discusses the prefabrication method in the State-Owned Enterprise (BUMN) project, Perum Perumnas. Perum Perumnas was founded on July 18, 1974, to provide housing for low-income groups. Perum Perumnas was established on a non-profit basis of government public services (Bahril, 2016). Perum Perumnas has products such as residential, vertical housing, and rusunawa. Several types of residential are Rumah Sederhana Sehat (RSh), Rumah Sederhana (RS), Rumah Menengah (RM). Sejuta Rumah and the 1000 Tower Program have encouraged Perumnas to start a new chapter to return to the city center to organize the city and build rusunami to get its residents closer to work or other activities. Rusunawa is simple flats rented out to urban people who cannot afford to buy a house or want to live for a while, such as students, temporary workers, and others (*Residensial – Perum Perumnas*, n.d.). Housing infrastructure challenges such as the housing needs of the millennial generation (population in 2019 around 81 million), the large number of backlogs (7.6 million houses), and improving the quality of housing and settlements (Rukmana, 2019). Perum Perumnas is committed to sustainable development harmony between economy, environment, and social aspects. These three aspects are commonly mentioned as a triple bottom line, or 3P (profit, planet, and people), which are interrelated and inseparable at once is the effort of Perum Perumnas in support Sustainable development Goals (SDGs) adopted by Indonesia into SDGs Indonesia (Wibowo, 2019). Several innovations in the construction sector have been discussed, such as Building Information Modeling (BIM) for the construction process, methods, and intelligent model-based management, which provides insight into the fields of Architecture, Engineering, and Construction to plan, design, build, and manage buildings and infrastructure with more effective and efficient. (Quiter, 2012). Integrating building information modeling and prefabrication housing production can help develop BIM and Prefabrication Housing Production (PHP) system architectures, benefitting multiple stakeholders to facilitate integration (Li et al., 2019a).

Schedule risks in prefabrication housing production in Hong Kong: a social network analysis. This study applies social network analysis (SNA) to identify and investigate the underlying network of risk factors related to stakeholders in prefabricated housing construction projects (Li et al., 2016). The simulation of the three prefabricated construction methods shows that the cost of the prefabricated method in Surabaya is still higher than the conventional method. In terms of time, prefabricated methods can shorten the time to 8 months to 14 months faster than the traditional method. In addition, prefabricated material products are guaranteed quality because they are produced in a factory with better machine processes and quality control, and more attention (Susanto, 2019).

Application of modular components with prefabrication methods of Rusunami Modular Buildings Kiaracondong shows development costs, lower construction, and faster for a national program of 1000 tower flats (Sunaryo & Meta, 2016). Modular construction falls outside the confines of multi-story building construction and is extensively introduced into multi-story and high-rise construction. In this direction, energy-efficient construction technologies are used. Material resources, environmentally friendly production, and the latest engineering equipment and materials are developed (Generalova et al., 2016).

Although modular construction is widely used in low-rise buildings, its application in high-rise buildings is still limited. The technical challenges hindering the widespread adoption of modular structures for high-rise buildings are highlighted and discussed (Thai et al., 2020). However, they were reducing building life cycle carbon emissions through Prefabrication. Prefabricated buildings, in general, have lower embodied and operational carbon emissions than their conventional method (Teng et al., 2018). The prefabricated and assembly construction technology of underground structures has the advantages of shortening the construction period, reducing overall project costs, protecting the green environment, conserving energy and reducing emissions, and eliminating winter construction problems (Yang & Lin, 2021). This research explains the advantages of prefabricated construction methods and offers an alternative method as a form of innovation for Perum Perumnas.

Methods

This innovation's scope compares costs and implementation times between conventional and Prefabrication methods. Commonly, there are four prefabricated system types: fully modular, sectional, component, and hybrid (Li et al., 2019b). Table 1 describes the features and basic modular types for each design. In this research, prefabrication methods are fed into the component system, such as multilevel column, beam, and slab with a simple layout (custom) are shown in Figure 1 shows 15 floors.

The prefabrication method is an alternative solution based on the SWOT analysis. An explanation of the SWOT analysis can be seen in the following Table 2. This model can provide information about the required strategy and the attitudes needed to adopt the chosen method. The strategy selection model is mainly based on the SWOT analysis of the selected Perum Perumnas. Therefore, it can also use other Perum Perumnas to rationalize their prefabrication strategy, this model is an open system, and its factors can be changeable.

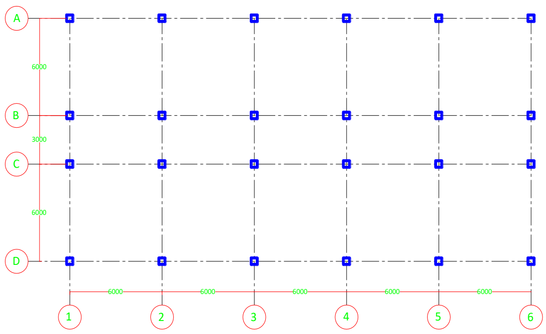


Figure 1. Layout high rise building (apartment)

Table 1. System types of prefabricated

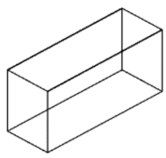
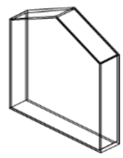
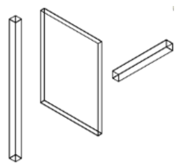
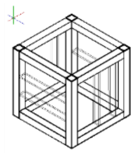
	Feature	Basic Module
Fully modular system	All unit housing components are fabricated, assembled, and manufactured as triple module dimensions (forming a box). The system requires a joint simple to the foundation and main structure. Modular unit sizes are limited by law highway or delivery constraints.	
Sectional system	Section modules for transport quickly and has some potentials for digital fabrication.	
Component system	Home fabrication system in the form of building components pre-designed and planned to be assembled in various ways.	
Hybrid system	A hybrid system combines prefabricated columns and beams to form a structural system fundamental in the building. In addition, this system gives the possibility to divide the building into two abstract elements.	

Table 2. SWOT analysis of the current high rise Perum Perumnas project

SWOT	Strength :	Weakness :
	1. Application of TOD with the concept of mixed-use for efficient land use. 2. The creation of sustainable transportation with short distances saves energy. 3. Have an internal institution to support the application of modern methods	A high rise building's construction requires significant time and working capital, causing an imbalanced investment turnover.
Opportunity : The level of housing needs increases every year. Therefore, the provision of housing facilities and infrastructure must be efficient. As a result, the distribution of services and goods is more evenly distributed, the lifestyles and cultures are more varied, the socio-economic vitality increases.	1. Make use of existing HR competencies and software applications to develop the TOD concept 2. We are utilizing BUPP in the production of prefabricated components.	1. Conducting training/knowledge sharing about software and applications in the era of the industrial revolution 4.0 to improve HR competencies 2. Improve the efficiency of working capital
	S - O	W - O
Threat : High competitiveness towards the offering of the TOD concept development demands global competition based on developing issues.	Providing socialization on the development of global issues hence that the innovations developed are right on target	Creating a strategy to attract investors to invest
	S - T	**W - T**

Perum Perumnas needs to be developed various alternative engineering concepts. The price of building construction can be affordable for the lower middle class, such as knock-down and pre-cast systems (YP. Suhodo Tjahyono, 2004).

Perum Perumnas must restore its role as the leading actor to provide housing for low-income people and do not follow market mechanisms that impact the number of housing developments (Bahril, 2016), and Perum Perumnas requires innovative marketing strategies to increase the number of consumers (Cendriyansyah & Mustikasari, 2017).

The reason for choosing a prefabricated component system is to maximize the utilization of the structure behavior's material characteristics. For example, in the dominant column structural elements, there is axial compressive force. Hence, this concrete material is suitable for column elements because concrete has high compressive strength. While the dominant beam structural element occurs bending force, steel is ideal for beam elements because steel has high flexibility.

Furthermore, steel also has a high strength-to-weight ratio; this indicates that optimal planning will result in a lighter foundation system. In addition to saving foundations, lightweight buildings are also helpful for earthquake-resistant building planning. By maximizing these materials' characteristics, it is expected that an optimal structural design will be obtained to reduce production costs. Innovation process flow can be seen in Figure 2.

Results

Structure design

To determine the effect of improving cost and time, designing a two-methods toy process can be compared. For the conventional method, column and beam planning uses reinforced concrete, while for the prefabricated form, column planning uses reinforced concrete and beams using steel.

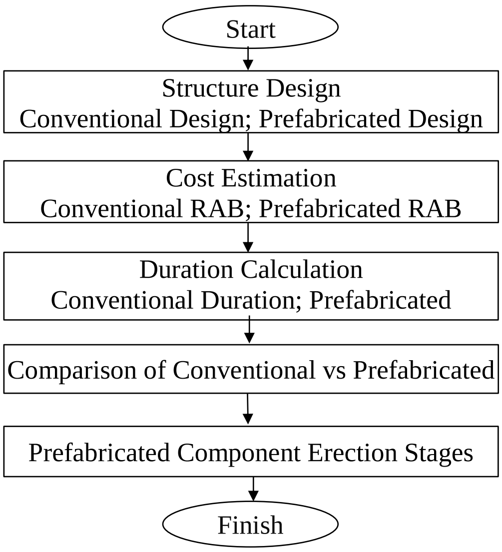


Figure 2. Innovation process flow

Planning standards

The planning standards used in structural calculations in this innovation are SNI 2847-2013, requirements for structural concrete for buildings.

(Nasional, 2013b), SNI 1729-2015, specification for structural steel buildings. (Nasional, 2015). SNI 1727-2013, minimum load for building planning. (Nasional, 2013a). SNI 7394-2008, procedure for calculating concrete work unit prices for building and housing construction (Nasional, 2008). SNI 1726-2012, earthquake resistance planning procedures for building and nonbuilding structures. (Nasional, 2012).

The material specifications used are as follows:
Quality of Concrete = 30 MPa
Steel Reinforcement = BJTD 400 MPa
Steel Structure
JIS SS400 fy = 245 MPa
Fu = 400 MPa
Bolts = Hi-Tensile Bolt Grade 8.8
Software used for modeling and structural design is STAAD.Pro V8.I by Bentley System, inc.

Conventional structure design

Reinforced concrete uses a preliminary design to determine the section's initial dimensions. Based on the calculation, the column and beam dimensions in Table 3 are in cm as follows.

Table 3. The column and beam dimensions

Code	Dimension
K1	45 x 45
K2	40 x 40
K3	35 x 35
B1	45 x 30
B2	30 x 20
B3	45 x 30
B4	30 x 20

The following Figure 3 and 4 shows the apartment structure modeling (high rise) to be designed.

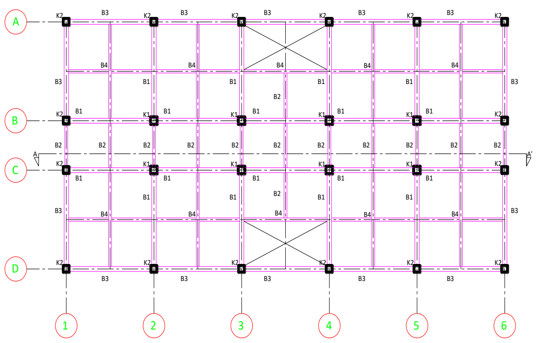


Figure 3. Conventional beam and column plan layout for floors 2-7

The size of the load and the combination of conventional and prefabricated loading refers to SNI 1727-2013 and SNI 1726-2012 in Figure 4 and modeling of conventional apartment structures in Figure 5.

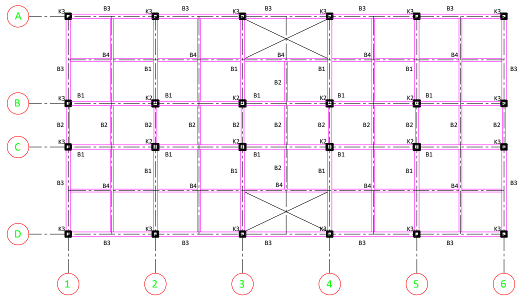


Figure 4. Conventional beam and column plan layout for floors 8-15

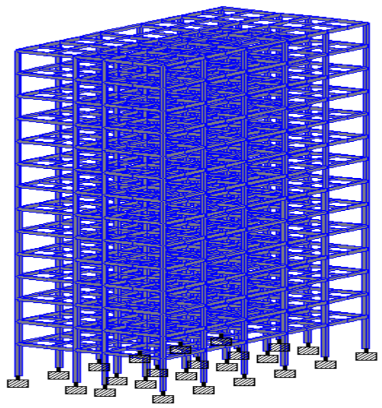


Figure 5. Modeling of conventional apartment structures

The dead load consists of the structure's weight, the finishing load (Ceramics, ceiling, MEP), and the wall load. The live load used is the residential floor load, which is 1.92 kN/ m².
Wind load as follow:
External Pressure (qz x G x Cp)
Wall Pressure Coff Coefficient)
Length, L = 30,00 m
Length, B = 15,00 m
L/B = 2,0
Windward wall = 0,8
Leeward wall = - 0,5
Side wall = - 0,7
Velocity pressure

$$q_z = 0{,}613.K_z.K_{zt}.K_d.V^2.I \quad (1)$$

Exposure type = C
Velocity pressure exposure, Kz
For z < 15 ft

$$K_z = 2{,}01.\left({}^{15}/_{z_g}\right)^{2/a} \quad (2)$$

For 15 ft ≤ z ≤ 900 ft

$$K_z = 2{,}01.\left({}^{z}/_{z_g}\right)^{2/a} \quad (3)$$

Topographic Factor, Kzt = 1,00
Wind Directionality Factor, Kd = 0,85
Wind Speed, V = 40,0 m/s
Importance Factor, I = 1,00
Gust Effect Factor (G) = 0,85

Based on Table 4 ASCE 7-05, internal pressure coefficient, GCPi determined based on the classification of building closures.

Table 4. Internal Pressure Coefficient

Enclosure classification	GCpi
Open building	0
Partial enclosed buildings	+0,55 - 0,55
Enclosed building	+0,18 -0,18

Enclosure Classification = 0,18
Wind force (p)

$$p = q.G.C_p - q.G.C_{pi} \quad (4)$$

According to the present Indonesian Earthquake Code, the structure is designed to resist seismic motions (SNI 03-1726-2012/ASCE 7-10). EQ Parameters obtained from PUSKIM (puskim.pu.go.id) based on project location (Jakarta). The following Table 5 shows Seismic Design Parameters.

Table 5. Seismic design parameters

Parameters	Value
PGA (g)	0,361
SS (g)	0,688
S1 (g)	0,299
Fa	1,324
Fv	2,802

Some parameters obtain from the code are Importance factor be taken as 1,0 (Table 1. SNI 03-1726-2012), and Effective seismic mass is taken as = DL + LL (no reduction). Combination of load as follow :

1,4 DL
1,2 DL + 1,6 LL + 0,5 LLr
1,2 DL + 1,6 LLr + 0,5 WIND X
1,2 DL + 1,6 LLr + 0,5 WIND Z
1,2 DL + 1,0 WIND X + LL + 0,5 LLr
1,2 DL + 1,0 WIND Z + LL + 0,5 LLr
0,9 DL + 1,0 WIND X
0,9 DL + 1,0 WIND Z
1,2 DL + 1,0 EQX + 1,0 LL
1,2 DL + 1,0 EQZ + 1,0 LL
0,9 DL + 1,0 EQX
0,9 DL + 1,0 EQZ

The beam is checked for bending, shear, and torsion. The type of collapse designed for beams is tensile collapse. The kind of failure designed in the beam is a compressive failure from the calculations that have been done (the strength requirements are met); the following Figure 6 and 7 section details are obtained. After checking, the deflection in Table 6 that occurs does not exceed the permissible deflection so that the structure can be rigid (stiffness requirements are achieved).

Table 6. Deflection criteria for structure

Deflection	Value	Load conditions
Vertical	L/120	DL
	L/360	LL
	L/240	DL + LL
Horizontal (for Column)	H/200	DL + Wind
Lateral Drift	0,020 H	EQX, EQZ

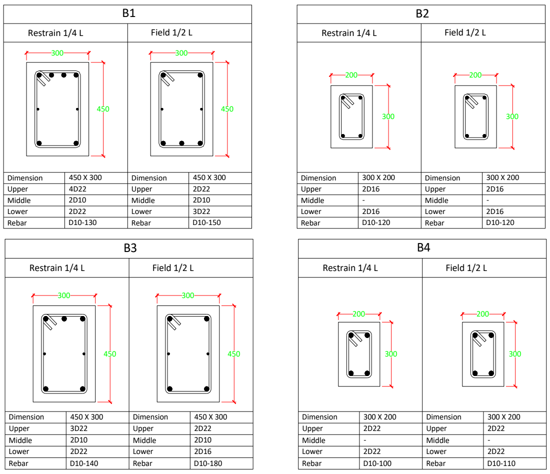


Figure 6. Details of the cross-section of reinforced concrete blocks

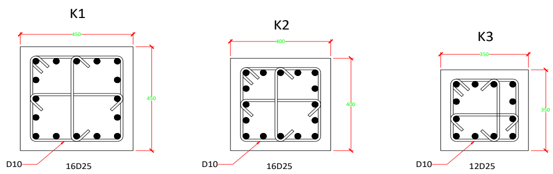


Figure 7. Detailed Section of Conventional Columns

Prefabricated structure design

Geometry of structures

The prefabricated components consist of reinforced concrete columns with steel beams. Previously it was explained that to determine the initial dimensions of reinforced concrete using a preliminary design. The section's initial dimensions are determined by the trial and error method for steel. The following figure shows the apartment structure modeling that will be designed using prefabricated components.

Beam cross-section

The stress ratio is defined as the ratio between the internal and steel profile's capacity. Check the voltage ratio using STAAD. Pro software. Based on the checks carried out, the voltage ratio is <1.0. This means that the strength requirements are met. Three types of steel profiles will be used; the steel profiles placement can be seen in Figure 8,9 and 3D modeling of prefabricated apartment structures Types of profiles used and presented in Figure 11.

Column section

The calculation of prefabricated columns follows conventional column calculations. From the calculation results obtained the following details Figure 12.

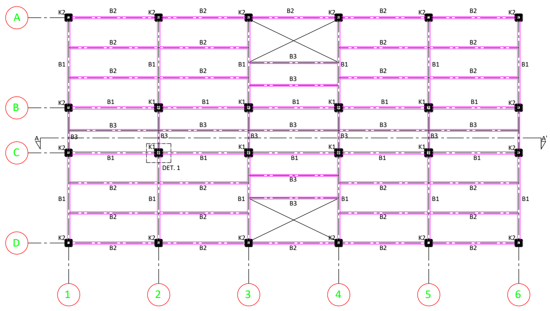


Figure 8. Prefabricated beam and column plan layout for floors 2 – 7

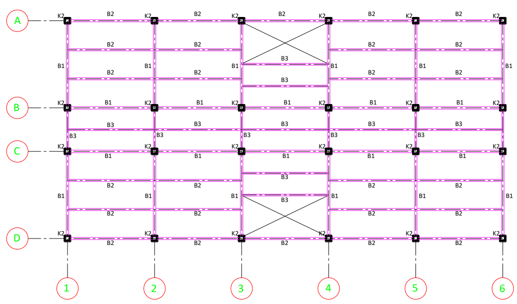


Figure 9. Prefabricated beam and column plan layout for floors 8-15

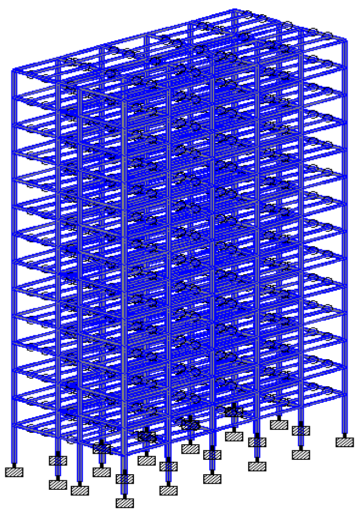


Figure 10. 3D Modeling of prefabricated apartment structures

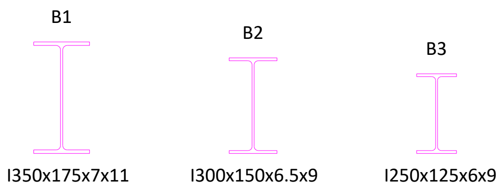


Figure 11. Steel profile used

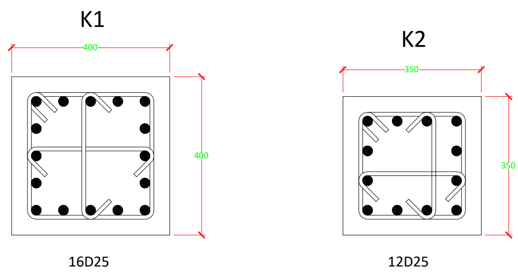


Figure 12. Detail of prefabricated column cross-section

One of the differences between reinforced concrete construction and steel construction lies in joint elements. Only one joint type is used in reinforced concrete, such as the joint moment (fix). However, two types of steel joints are used: joint moment and sleeve joint. Generally, the joint moment type connects beam elements and columns (on the Primary Beam). The sleeve joint is used in the Primary Beam and Secondary beam relationship. The choice of joint type considers the erection implementation in the field. The kind of joint moment used is the extended endplate. The sleeve joint uses a simple joint type using a gusset plate. Details of the joint can be seen in Figure 13,14 below.

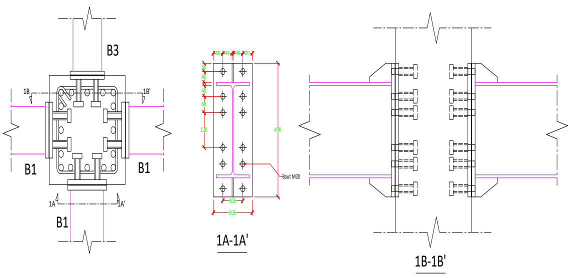


Figure 13. Extended end plate details

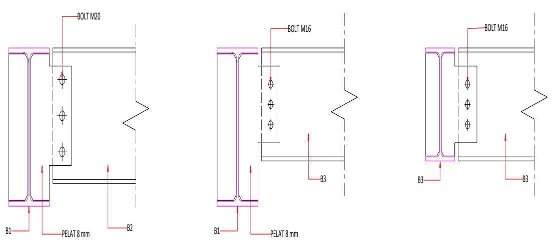


Figure 14. Sleeve joint details

The summary of the total volume for each structural element before calculating the cost can see in Table 7. The recapitulation of the budget estimate plan of implementing the upper structure with conventional methods can be seen in Table 8.

Prefabrication Budget Estimate Plan

The recapitulation of the budget estimate plan of implementing the upper structure with prefabrication methods can be seen in Table 9.

Table 7. Summary of volume upper structure

Work Item	Unit	Volume
Structure		
Column		
K1 Size 45 X 45	m³	42,120
K2 Size 40 X 40	m³	97,936
K3 Size 35 X 35	m³	48,020
Beam		
B1 Size 45 X 30	m³	190,512
B2 Size 30 X 20	m³	29,484
B3 Size 45 X 30	m³	148,176
B4 Size 30 X 20	m³	84,840
Slab	m³	735,706

Table 8. Recapitulation of costs for conventional methods

No	Job description	Total price (IDR)
1	Column	1.700.735.954,56
	Beam	2.535.100.477,25
	Slab	4.595.354.167,26
	Tower Crane Operating Costs	2.936.412.000,00
2	Amount	11.767.602.599,16
	PPN 10%	1.176.760.259,92
	Total	12.944.362.859,08

Table 9. Recapitulation of Costs for prefabrication methods

No	Job description	Total price (IDR)
1	Column	1.562.357.712,76
	Beam	5.597.395.818,67
	Slab	2.753.666.754,30
	Tower crane operating costs	1.064.664.000,00
2	Amount	10.978.084.285,74
	PPN 10%	1.097.808.428,57
	Total	12.075.892.714,31

From the calculation of the estimated cost of implementing the two methods (prefabrication and conventional), the comparison of the expenses per work item in Figure 15 shows the comparison of the cost work item. Figure 15 obtained a cost efficiency of 7% (deviation = 868.47 million). High building costs are required with increased expectations for higher quality at a lower or stable budget, so construction costs need to be accurately estimated and managed as one of the critical decision-making elements (Ferry & Brandon, n.d.). The budget estimate plan calculation amount refers to the UMSP DKI Jakarta Pergub Number 16 of 2018. The amount of material value refers to the material value of Jakarta City in 2018.

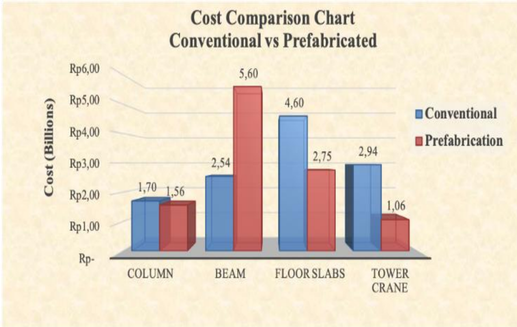


Figure 15. Conventional vs. prefabricated cost comparison

Prefabricated structure design time estimation

The estimated time required to complete upper structure work using conventional methods is 557 days in Table 10. In comparison, the time needed to complete upper structure work with prefabricated methods is 186 days in Table 11, assuming the working time is eight hours per day. For the estimated duration of the two methods, it can be seen that the prefabrication method is two to three times faster than the conventional method.

Table 10. Recapitulation of time for conventional methods

No	Work item	Duration (days)
1	2nd Floor	44
2	3rd Floor	40
3	4th Floor	40
4	5th Floor	40
5	6th Floor	40
6	7th Floor	40
7	8th Floor	40
8	9th Floor	39
9	10th Floor	39
10	11th Floor	39
11	12th Floor	39
12	13th Floor	39
13	14th Floor	39
14	15th Floor	39
	Work structure total	557

Prefabricated component erection stages

The erection stages of prefabricated components are as follows in Figure 16: Conventional column manufacturing stage ± ½ h for the first floor. The purpose of traditional columns is to have a monolithic column structure with a foundation structure.

Table 11. Recapitulation of Time for Prefabrication Methods

No	Work Item	Total	Duration (days)
1	Column for each floor	24	2
2	Beams for each floor	63	4
3	Steel deck for each floor		6
Working total for three floors			186

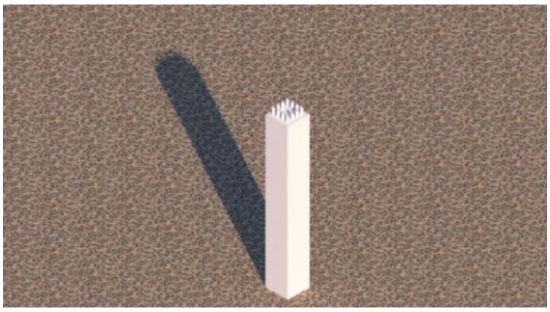


Figure 16. Conventional column stage

The scaffolding installation stage temporarily holds the precast column components to be installed. The material used for the scaffolding in Figure 17 is the IWF 150x75x5x7 steel profile.

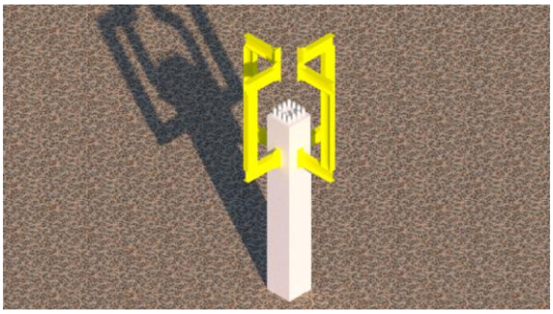


Figure 17. Scaffolding installation stage

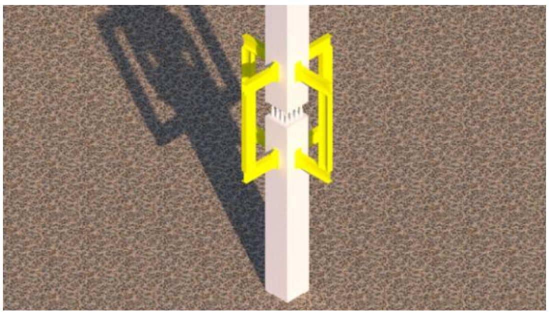


Figure 18. Precast column components.

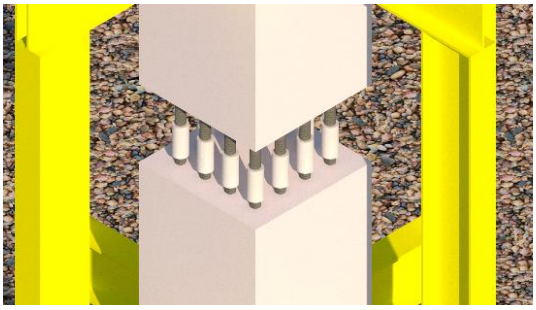


Figure 19. Joint details of precast components

Erection of precast column components. The joint type between precast components in Figure 18 used is a wet joint. The wet joint is longitudinal rebars that protrude from the ends of each precast concrete component spliced by grout sleeve, welding, or lap-splicing (Li et al., 2019a). The goal is that the column structure becomes a monolith. The joint between the rebar using a coupler. Details of the joint can be seen in Figure 19 below.

Process of Grouting Joint for Precast.

After the grouting process in Figure 20 is followed by direct steel beam erection work and Erection of steel beam components in Figure 21

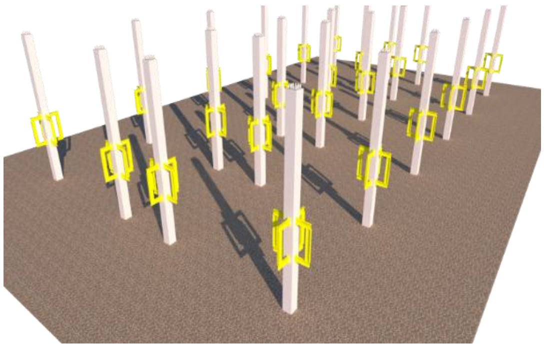


Figure 20. Grouting joint for precast

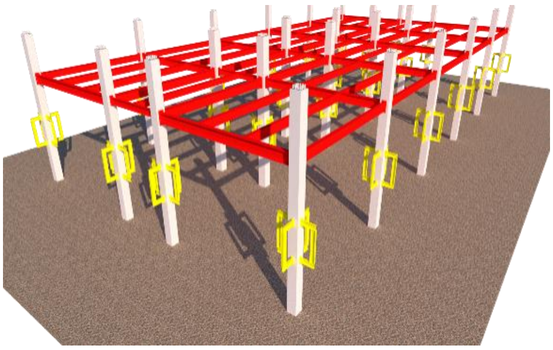


Figure 21. Erection of steel beam components

Slab pouring concrete stage in Figure 22. The slab uses the bondeck system without formwork.

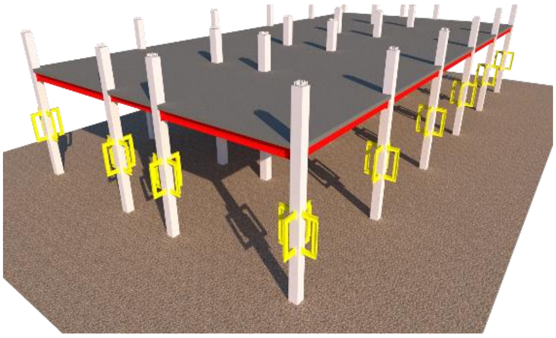


Figure 22. The pouring concrete of slab

The next stage, repeat from stage 2 to 6 for the erection of each floor and erection 3rd floor can be seen in Figure 23 below.

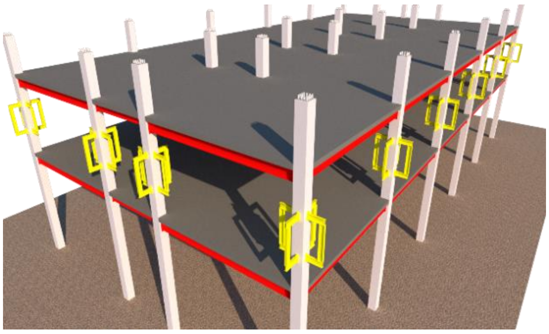


Figure 23. Erection 3rd floor

The contribution to be achieved is to increase knowledge in civil engineering, especially innovation of prefabrication construction that can be applied practically in the field. The high-rise building project that has been built previously uses a dry connection between columns, while this research uses a wet connection and the existing method of precast concrete columns-steel beams is used in the construction of long distances between columns and requires steel for the beams. Usually in buildings whose function such as ballrooms and sports. Meanwhile, in this research, the function is an apartment. Thus, the innovations that have been found can be used in other High-rise Building Projects.

Conclusion

The calculation of the structure carried out by the prefabrication method in the High Rise Building Project of Perum Perumnas shows the efficiency of costs, time, and work duration. Other benefits are in line with the 2030 sustainable development agenda known as SDGs (Sustainable Development Goals).

SDGs with the No-one Left Behind concept encourages change and sustainable development based on human rights and equality to achieve the four pillars of goals, such as social, environmental, economic development, and law and governance.

The risk analysis of this Prefabrication can repair prefabricated components in the field. The fault tolerance is minimal (in mm). It requires high accuracy and control when manufacturing prefabricated components during erection.

For further research, it is necessary to carry out a risk analysis on the innovations that will be applied to minimize the risk opportunities that will occur, involve the Perumnas Prefabricated business unit in producing column components, and need to develop innovations to create variations of prefabricated components that are more affordable.

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