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Efficiency of Using PERI Formwork in Low-Rise Buildings Project

M. Natalia[1], H. Alexander[2], M. Misriani[3*], M. Zaqharia[4], D. Kurniawan[5]

[1,2,4,5]*Civil Engineering Department, Padang State Polytechnic, Padang, Indonesia*

[3*]*Civil Engineering Department, Faculty of Engineering, Riau University, Pekanbaru, Indonesia*

E-mail: [1]monikanatalia75@gmail.com , [2]hendra.alexander@gmail.com ,

[3]merley.misriani@eng.unri.ac.id, [4]muhammadzaqha2017@gmail.com,*

[5]danikurniawan.62@gmail.com.

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A B S T R A C T

Concrete construction is still the main choice because of its high strength, durability, and ability to withstand heavy loads. In reinforced concrete construction, formwork is a fairly important element. Formwork significantly impacts the efficiency of construction implementation. Formwork innovation has found PERI formwork to be a solution that many consider more efficient. Efficient use of PERI formwork is an important focus to increase productivity, minimize time, and reduce construction costs. This research aims to analyze the quality, cost, and implementation time of PERI formwork compared to conventional formwork in 2-story buildings. Quantitative methods are used to evaluate quality (strength of bending, safe deflection, and strength of the shear) using SAP 2000, implementation time using Microsoft Project, and project costs using unit price analysis. The research results show that using the PERI formwork system can provide various efficiencies in formwork work. PERI formwork has been proven stronger in withstanding loads and meets current load regulations. It can save project implementation time by up to 21 working days (24.7%) with a cost reduction of 4.72%. This is because the installation cycle is faster, which can increase productivity and reduce costs. So, using the PERI system formwork has proven efficient and can be the best choice for low-rise building construction projects.

1. Introduction

National Strategic Projects (PSN) continue to be built by the government on an ongoing basis to accelerate infrastructure development while supporting economic equity programs, improving connectivity, and strengthening strategic sectors [1], [2]. The National Long Term Development Plan (RPJPN) 2025-2045 will still focus on infrastructure

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development by optimizing built infrastructure through the development of downstream industrial areas connected to connectivity infrastructure, maintaining consistency of central and regional development, and orchestrating all development actors that are not only focused on the government but also on the private sector and the general public. Based on the Coordinating Minister for Economic Affairs Regulation Number 7 of 2023, 211 projects and 13 programs are on the PSN list with an estimated total investment value of Rp5,746.9 trillion. The projects are spread across several sectors, including developing connectivity infrastructure such as ports, toll roads, railways, and airports, improving energy security, developing industrial areas downstream, and providing basic infrastructure [3].

In this development context, concrete construction is still the main choice due to its durability and ability to adapt to various environmental conditions. In reinforced concrete construction, formwork is a fairly important element. Although only as a temporary construction, formwork requires planning, long processing time, and much costs, an estimated 10 percent of the total construction cost [4], [5]. Formwork is a temporary mold used to hold concrete, during which concrete is poured and shaped according to the desired shape. Formwork will be dismantled once the cast concrete reaches adequate strength [4]. Formwork costs have a fairly high percentage in multi-story structure work. Formwork costs range from 40 to 60 percent of the total concrete cost. With such a large cost level, formwork is particularly interesting to construction projects, especially the methods used. If not, it can lead to cost overruns and delays in project completion, considering that the next work, namely ironing and casting concrete, depends on this formwork work [5].

The choice of formwork type is an important decision in construction projects because it affects the cost, time of work, and quality of construction. Time and cost optimization can potentially accommodate the efficiency of the implementation of construction project formwork [6]. Formwork work initially only uses wood (conventional), which has the disadvantage of waste material that can no longer be used for further formwork work [7], [8]. By paying attention to sustainable aspects, conventional formwork is replaced by other materials [9]. Usually, formwork consists of two types: conventional and system/fabricated. Conventional formwork is made from wooden planks or multiplex and wooden beams. The formwork parts are assembled and installed at the project location (in situ) and done using manual/straightforward tools [10], [11]. This formwork is generally only used for 2-3 jobs, considering that the components can still be used for the following process [12]. Conventional formwork has good flexibility and is still an option for the construction industry in Indonesia.

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In contrast, this type of formwork is not environmentally friendly, generates construction waste, and depletes wood resources [10]–[14].

In construction, technological innovation that prioritizes efficiency in terms of quality, time, cost, and attention to aspects of environmental sustainability is needed [15]–[18]. The rapid development of technology has revolutionized manual/conventional formwork with semi-system formwork such as scaffolding, knockdown, and system formwork such as PERI system formwork, aluminium formwork, fiberglass formwork, kumkang, aluma system, table form, etc [10], [13], [19]–[21].

PERI system formwork is prefabricated formwork consisting of components, mostly made of steel, designed for repeated use. The formwork system's (PERI) advantages are easy installation and dismantling, lightweight, repeated use, quality casting, and fast dismantling, and can be used in large concrete construction projects [22],[4], [23], [24]. The disadvantage of the formwork system (PERI) is that it is expensive and requires expertise and heavy equipment, but for time, it is faster than conventional [5]. The formwork system method is recommended if the construction project needs to be completed more quickly [25]. Evaluation of the use of conventional formwork and the PERI system in the outfall construction project shows that the system formwork cost is more expensive. In terms of quality, the conventional formwork has defects in the flatness of the joints and is easy to leak and rust, but the PERI formwork has satisfactory quality. In terms of construction time, conventional formwork has a longer time than PERI formwork [26]. However, in contrast, the results of other studies stated that the cost of using the PERI system formwork is cheaper than conventional formwork [11]. Several studies have examined comparing quality, time, and costs between conventional formwork and PERI, obtaining varying results. This is because the building objects studied are different. The wider and higher the building construction, the cheaper it is to use system formwork compared to conventional formwork.

However, further studies are needed to investigate the effectiveness of using PERI formwork compared to conventional formwork, especially in low-rise buildings. This research aims to analyze the quality, costs, and time of implementing PERI formwork compared to conventional formwork in a 2-story building. It is hoped that this research recommends the best formwork that is cheaper, faster, and meets quality standards for implementation in low-rise building projects.

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2. Research Methods

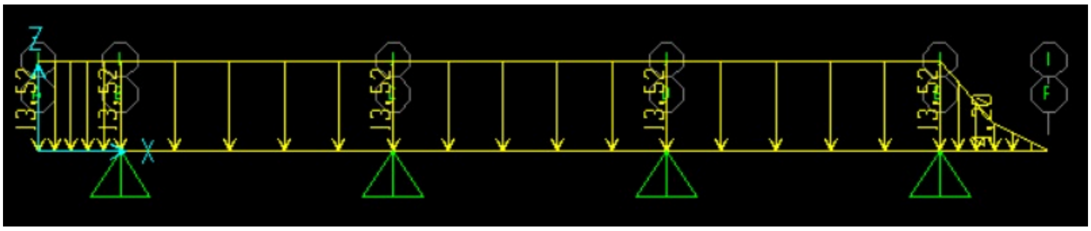
This research used quantitative methods with the object of a 2-story building using a reinforced concrete structure with a building area of ± 3,360 m2 and a building height of ± 17 m, using two types of columns, namely columns (70x70 cm and 60x60 cm), using six types of beams (40x80 cm, 40x70 cm, 40x65m, 30x60 cm, 30x50 cm, 30x40 cm) and floor slabs 12 cm thick. The data needed in this research are shop drawings and DED, technical specifications, prices, wages, and materials. Data processing and analysis stages include strength analysis of formwork for columns, beams, and slabs, work time, and cost analysis. Then, compare the planned cost budget, quality, and implementation time required for conventional and PERI formwork.

2.1 Data

The data used in this research includes shop drawings, Detail Engineering Design (DED), and technical specifications. Meanwhile, other data for quality, such as the strength of the bending, safe deflection, and strength of the shear prices, using PT Beton Perkasa Wijaksana document. Prices for wages and materials using the Padang City work unit price (HSP) in 2022. Apart from that, analysis of work unit prices (AHSP) using PUPR Ministerial Decree No. 1 of 2022.

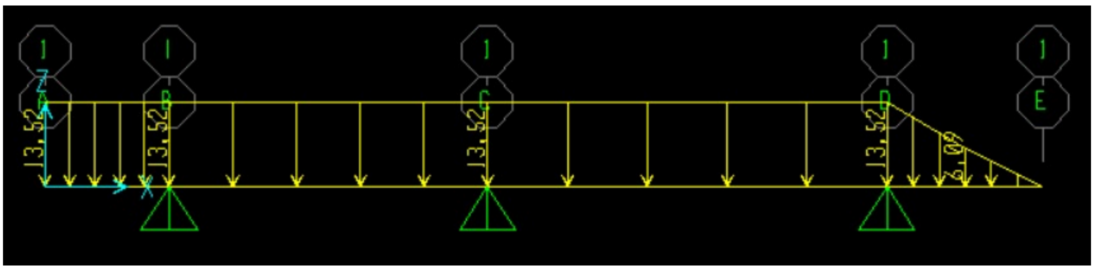
2.2 Data Processing and Analysis

Strength analysis is done by loading on beams, columns, and slabs. Calculations using SAP 2000 application.



Source: Author Research Method.

Figure 1. Modeling Quality Testing of Conventional Formwork.



Source: Author Research Method.

Figure 2. Modeling Quality Testing of PERI Formwork.

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Each column formwork has a multiplex with the same thickness, but the difference is the support and binding of the multiplex. Conventional formwork uses 6/12 wood and an adjusted belt distance so that the column is safe when a load is applied. Meanwhile, the PERI system uses girders and is tied with column wales, the distance of which has been determined based on the PERI system reference book. Modeling in SAP 2000 is carried out with a span of 3m and is supported with a tested distance and given a load q1 of 13.524 kg/cm and q2 of 6.09 kg/cm. After that, calculations of maximum bending, deflection, and shear, which must meet safe construction conditions, are carried out. Strength analysis is carried out by checking strength bending, safe deflection, and shear strength. The analysis was conducted based on Indonesian Wood Construction Regulations (PPKI) NI – 5 1961; Concrete Standards Regulations 1991 (SK.SNI T-15-1991-03), 347 – Recommended Practice for Concrete Form Work; SP4, Special publication 34 – Form Work for Concrete. After obtaining the type and size data of the formwork plan, calculate and analyze the unit price of work, including wages, materials, and tools for using conventional formwork and the PERI formwork system in column, beam, and slab. A budget plan for both types of formwork is obtained. Time analysis is carried out by dividing the work area into two zones per floor and using two sets of formwork. Each floor has the same size and area (typically from the 1st to the 2nd floors). The duration of each work item is calculated based on volume and productivity. The total formwork implementation time (conventional and PERI system) was analyzed based on WBS and division of work zones, and then the Microsoft Project application was used. Furthermore, a comparison of the quality, cost, and time of using conventional formwork and PERI system formwork was analyzed.

3. Results and Discussions

3.1 Quality Analysis

They analyzed quality of formwork to be used based on the load of the column, beam, and slab, which shows the strength of bending, safe deflection, and strength of the shear in **Table 1**.

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Table 1. Quality and Type of Formwork.

	Formwork	Strength of the bending (kg/cm^2)	Safe deflection (cm)	Strength of the shear (kg/cm^2)
A	Conventional Formwork			
1	Column			
	multiplex 15 mm	34,1 ≤ 100	0,079 ≤ 0,35	12 ≤ 118
	wood beam 6/12	85,5 ≤ 100	0,001 ≤ 0,2	9,6 ≤ 12
2	Beam			
	Static side form beam			
	Multiplex 15 mm (direction x)	70,6 ≤ 100	0,11 ≤ 0,116	2,02 ≤ 12
	Multiplex 15 mm (direction y)	18,5 ≤ 100	0,098 ≤ 0,227	0,272 ≤ 12
	Static bottom form beam			
	Multiplex 15 mm (direction x)	62,93 ≤ 100	0,10 ≤ 0,13	1,57 ≤ 12
	Multiplex 15 mm (direction y)	59,2 ≤ 100	0,1 ≤ 0,1	1,692 ≤ 12
	Wooden rafters beam 5/7	60,1 ≤ 100	0,0368 ≤ 0,133	4,7 ≤ 12
3	Slab			
	Multiplex 15 mm	76 ≤ 100	0,01 ≤ 0,652	3,25 ≤ 12
	Wooden rafters beam 5/7	60,1 ≤ 100	0,0368 ≤ 0,133	4,7 ≤ 12
	wooden transverse beam 6/12	85,5 ≤ 100	0,001 ≤ 0,2	9,6 ≤ 12
	Dolken wood	50,3 ≤ 100	0,061 ≤ 0,15	3,6 ≤ 12
B	PERI system			
1	Column			
	Multiplex 15 mm	34,1 ≤ 100	0,079 ≤ 0,35	12 ≤ 118
	Girder		0,296 ≤ 0,74	
	Wale dan tie rod (Vario SGRZ)	376,6 ≤ 1600	0,001 ≤ 0,166	311,41 ≤ 928
2	Beam			
	Static side form beam			
	Multiplex 15 mm (direction x)	70,6 ≤ 100	0,116 ≤ 0,1167	2,02 ≤ 12
	Multiplex 15 mm (direction y)	18,5 ≤ 100	0,098 ≤ 0,227	0,272 ≤ 12
	Elbows on ankle beam	18,5 ≤ 100	0,059 ≤ 0,0875	0,272 ≤ 12
	Static bottom form beam			
	Multiplex 15 mm (direction x)	62,93 ≤ 100	0,1007 ≤ 0,13	1,57 ≤ 12
	Multiplex 15 mm (direction y)	59,209 ≤ 100	0,1 ≤ 0,1	1,692 ≤ 12
	Wooden rafters beam 5/7	60,1 ≤ 100	0,0368 ≤ 0,133	4,7 ≤ 12
	Elbows on ankle beam	18,5 ≤ 100	0,025 ≤ 0,1175	0,272 ≤ 12
3	Slab			
	Multiplek 15 mm	76 ≤ 100	0,01 ≤ 0,652	3,25 ≤ 12
	Wooden rafters beam 5/7	60,1 ≤ 100	0,0368 ≤ 0,133	4,7 ≤ 12

Source: Author Research Analysis (2023) and PT Beton Perkasa Wijaksana Document.

Table 1 shows that using materials for conventional formwork and PERI system formwork meets the strength analysis (strength of the bending, safe deflection, strength of the

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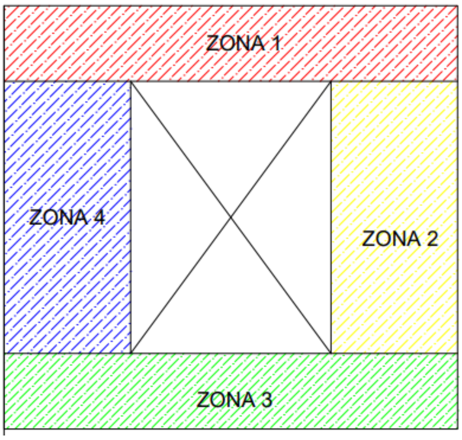
shear). Bending, deflection, and shear tests using multiplex, wood beam, and wooden rafters beam on conventional formwork and PERI work columns, beams, and slab have the same strength and meet specified safe limits. Column work in conventional formwork uses wood beam 6/12 with a deflection of 0.001 cm, safe from a required limit of 0.2 cm, for shear strength obtained 9.6, still within the required safe limit of 12 kg/cm2. Column work on PERI formwork using girders with a shear of 0.296, a still safe requirement of 0.74 kg/cm2. The column also uses wale and tie rod (vario SGRZ) to form a perfect column with a strength of bending value of 376.6, qualified ≤ 1600; deflection of 0.001, qualified ≤ 0.166, and safe from shear with a value of 311.41 still qualifies ≤ 928. Beam works on conventional formwork, and PERI uses the same material, mulitiplex, wooden rafter beams. The PERI system has additional elbows on the ankle beam, which is useful for locking formwork on the top and bottom of the beam. This elbow has a bending of 18.5, a safe requirement of 100 cm; it has a shear value of 0.272, safe a shear requirement of 12 kg/cm2. All materials and types of formwork used in this research are qualified strength of bending, safe deflection, and strength of shear. PERI's formwork system has been proven to be stronger in load bearing, produces high quality, and complies with current load regulations. The PERI system formwork has permission controls contained in the current loading regulations.

This is following several previous studies that have been conducted. PERI formwork has better strength than conventional formwork, does not leak, and is flat at the joints [26]. Conventional formwork has shortcomings in joint flatness, leaks, and rusts easily [27]. So in terms of quality, PERI formwork is better than conventional formwork.

3.2 Time Analysis

During the implementation of structural work, it is divided into four zones, and zone 1 is opposite zone 3 and zones 2 and 4, as shown in **Figure 3**.



Source: Author Research Method (2023).

Figure 3. Formwork Work Zones and Cycles.

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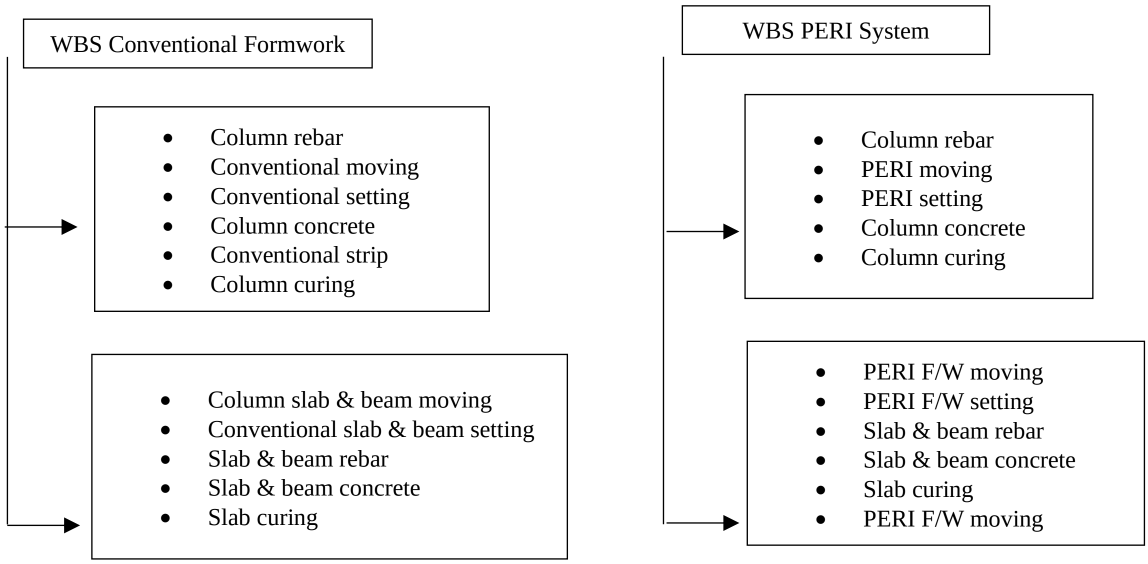
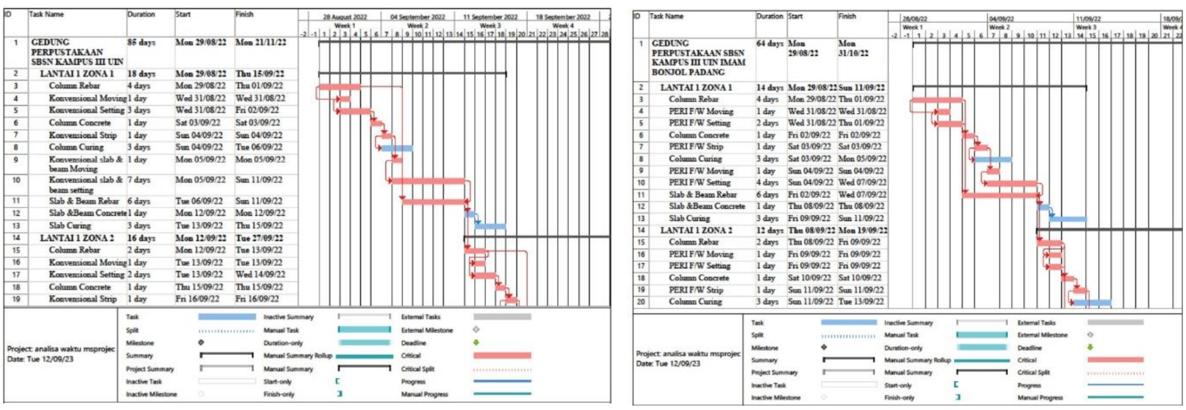
The formwork work uses two sets of formwork, where the work cycle of material from floor 1 zone 1, which has been dismantled, is moved to floor 1 zone 3, and floor 1 zone 2, which has been dismantled, is transferred to floor 1 zone 4 and so on until floor 3. Work Breakdown Structure (WBS) conventional formwork, as shown in **Figure 4 (a)**, and WBS PERI system formwork, as shown in **Figure 4 (b)**.



(a) (b)

Source: PT Beton Perkasa Wijaksana Document.

Figure 4. Work Breakdown Structure; (a) Conventional Formwork; (b) PERI Formwork.



(a) (b)

Source: Author Research Results.

Figure 5. Time Schedule; (a) Conventional Formwork; (b) PERI Formwork.

The total time required for column, beam, and slab formwork work using conventional formwork is 85 working days, and using the PERI system is 64. The use of PERI system formwork is faster than conventional formwork for 21 working days cause PERI formwork is

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designed for easy installation and disassembly, consists of several elements that can be installed and disassembled quickly, thus speeding up the construction process, fast installation cycle, the quality of concrete work is better so it can save time disassembly. Conventional formwork requires a longer time for installation because conventional formwork consists of heavier materials and is difficult to move. In addition, conventional formwork also requires a longer time for disassembly and replacement of new formwork.

This is following previous research where the PERI system formwork is faster than conventional formwork [24], [28], [29]. Implementing system formwork can shorten the time due to easy installation, resulting in high productivity levels [12], [29]. The height of the PERI formwork can reach 18 m in one panel. For high construction, big and typical, using the PERI formwork system will speed up the project implementation time. PERI formwork has an installation method with an all-in-one system or a single structural element that allows efficient implementation without any work left behind [30].

3.3 Cost Analysis

A recapitulation of the cost of conventional formwork and PERI system, cost differences, and comparison work is in **Table 2**.

Table 2. Recapitulation of the RAB for Conventional Formwork, PERI System, Cost Differences, and Comparison.

No	Job description	Volume	Conventional Formwork		PERI System Formwork	
			Unit price (IDR)	Total price (IDR)	Unit price (IDR)	Total price (IDR)
1	Column	1468,400	296.114,04	434,813,848.99	406.653,98	597,130,710.00
2	Beam	2922,398	305.567,75	892,990,566.85	322.887,70	943,606,364.10
3	Slab	2810,613	336.830,98	946,701,348.72	222.845,18	626,331,447.98
	Amount			2,274,505,764.57		2,167,068,522.08
	Cost Difference (IDR)					107,437,242.48
	Comparison (%)					4.72

Source: Author Research Analysis (2023).

PERI system formwork for columns is more expensive than conventional formwork. Conventional column formwork obtained a unit price of IDR. 296,114.04 with labor costs of IDR. 133,650.00, material costs IDR. 162,464.04. The unit price of the PERI system formwork is IDR. 406,653.98 with labor costs of IDR. 63,525.00, material costs of IDR. 44,720.00, and equipment rental costs of IDR. 298,428.98. Using the PERI formwork system, labor costs are cheaper at 52.5%, and material costs are cheaper at 72.5%. However, PERI formwork requires expensive equipment rental costs. So, the unit price difference is IDR 110,539.94, and it can be said that the PERI system formwork is more expensive.

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In conventional beam formwork, the unit price of work is IDR. 305,567.75 with labor costs of IDR. 133,650.00, material costs IDR. 171,917.75. The unit price of the PERI system formwork is IDR. 406,653.98, with labor costs IDR. 63,525.00, material costs IDR. 80,917.75, and equipment rental costs IDR. 178,444.95. Using the PERI formwork system, labor costs are cheaper by 52.5%, and material costs are cheaper by 53%, but it is expensive to rent equipment, while conventional formwork is without rental fees. So, the unit price of PERI formwork is more expensive at IDR. 101,086.23.

The use of PERI system formwork for slab is cheaper than conventional formwork. Conventional formwork slab obtained a unit price of IDR. 336,830.98 with labor costs of IDR. 133,650.00, material costs IDR. 203,180.98. The unit price of the PERI system formwork is IDR. 222,845.18, with labor costs IDR. 63,525.00, material costs IDR. 54,261.67, and equipment rental costs IDR. 105,058.51. Using the PERI formwork system, labor costs are cheaper (52.5%), and material costs are cheaper (73.3%). So that the unit price of PERI formwork is lower at IDR. 113,985.80.

Overall, the difference in work costs using conventional and PERI formwork is IDR. 107,437,242.48. The cost of formwork using the PERI System is 4.72% cheaper than conventional formwork. This is because the unit price of materials is relatively cheap, and workers' wages due to repeated use are high. Due to its ease of installation and disassembly, PERI formwork has the fastest installation time, resulting in high productivity. PERI system formwork is cheaper because it is easy to install and disassemble, can be used repeatedly, and has good quality circumvention, so the disassembly cycle is faster [30], [5].

The results of this research are in line with previous research where the total cost of the PERI system is cheaper than the cost of conventional formwork [12], [24], [29]. Using the PERI system will save costs up to 52.5% and material costs up to 73.3%. If the PERI formwork is not rented (owned), it will further save the overall construction cost.

Using the PERI system formwork can minimize costs because it does not use a lot of labor. The labor intensity in the installation and disassembly of formwork is much lower than conventional wooden formwork [31]. Installing the PERI formwork system is relatively easy, producing high productivity. Therefore, an important factor that influences the successful completion of a project is the choice of formwork material [32]. The PERI system formwork also supports the green construction concept of reducing wood use. Using PERI system formwork to replace conventional formwork will preserve the environment, not consume wood resources, and not produce construction waste.

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4. Conclusion

The PERI formwork system can provide various efficiencies in formwork work. This is shown by research results where the PERI formwork system is proven to be stronger in load bearing, produces high quality, and complies with current load regulations. In addition, using the PERI system formwork can save project implementation time by up to 21 working days (24.7%) and at a cost that is 4.72% lower than conventional formwork. This is because the installation cycle is faster, which can increase productivity and reduce costs. So, the PERI formwork system has proven efficient and can be the best choice for low-rise building construction projects.

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ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

References

[1] M. Priyanta and C. S. A. Zulkarnain, "Sustainable Infrastructure Legal Policy in Indonesia: A National Strategic Project Approach for National Development," *Sriwij. Law Rev.*, vol. 7, no. 1, pp. 1–18, 2023, doi: 10.28946/slrev.Vol7.Iss1.1108.pp1-18.

[2] D. R. Nisa and I. T. Sihidi, "Infrastructure Development and Conflict: A Conflict Resolution in The Construction of An Oil Refinery," *J. Ilmu Sos.*, vol. 21, no. 1, pp. 57–74, 2022, doi: 10.14710/jis.21.1.2022.57-74.

[3] P. A. Sungkono and H. F. Kurniawan, "Case Studies of Private Government Cooperation: Procurement of Land Development Projects Toll Road Krian – Legundi – Bunder – Manyar," *IJTI (International J. Transp. Infrastructure)*, vol. 2, no. 2, pp. 92–97, 2019, doi: 10.29138/ijti.v2i2.788.

[4] A. G. Manohara, E. W. Amelia, and Dika Adytia Pratama, "Pelaksanaan Bekisting atau Formwork," 2016. doi: 10.22146/jp.22589.

[5] H. S. Pratama, R. K. Anggraeni, A. Hidayat, and R. R. Khasani, "Analisa Perbandingan Penggunaan Bekisting Konvensional, Semi Sistem, dan Sistem (PERI) Pada Kolom Gedung Bertingkat," *J. KARYA Tek. SIPIL*, vol. 6, no. 1, pp. 303–313, 2017.

[6] Y. A. Nashir, "Optimalisasi Waktu dan Biaya Pekerjaan Bekisting Melalui Sistem Siklus Pemakaian dan Sistem Zoning Pada Gedung Bertingkat (Studi Kasus: Proyek Universitas Gadjah Mada Kampus Jakarta)," Universitas Indonesia, 2010.

[7] Y. Gamil, J. Nilimaa, M. Emborg, and A. Cwirzen, "Lateral formwork pressure for self-compacting concrete—a review of prediction models and monitoring technologies," *Materials (Basel).*, vol. 14, no. 16, 2021, doi: 10.3390/ma14164767.

[8] R. Baskova, A. Tazikova, Z. Strukova, M. Kozlovska, and J. Cabala, "A Dynamic Model for Effective and Optimal Planning of Formwork in Construction Projects," *Buildings*, vol. 13, no. 7, 2023, doi: 10.3390/buildings13071794.

[9] Mafriyal, M. Natalia, H. Alexander, F. Febriansyah, and A. A. Putra, "Analisa Biaya dan Waktu Penggunaan Aluma System dan Scaffolding Proyek Arandra Residence Jakarta," *Siklus J. Tek. Sipil*, vol. 8, no. 1, pp. 86–99, 2022, doi: 10.31849/siklus.v8i1.9560.

[10] O. Kurakova, "Use of formwork systems in high-rise construction," *E3S Web Conf.*, vol. 33, pp. 1–7, 2018, doi: 10.1051/e3sconf/20183303026.

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

[11] O. Guspari, M. Mafriyal, R. Hidayati, Z. Mirani, and P. Wike Amelia, "Analisis Perbandingan Biaya Pekerjaan Bekisting Konvensional dan Bekisting Sistem Pada Bangunan Gedung (Studi Kasus: Proyek," vol. 19, no. 1, pp. 68–76, 2022, [Online]. Available: http://ejournal2.pnp.ac.id/index.php/jirs.

[12] D. Rahadianto, D. Perwitasari, and A. R. H. Mashur, "Analisa Perbandingan Penggunaan Bekisting Aluminium, Bekisting Konvensional, Semi Konvensional Dan Sistem (PERI)," *Cived*, vol. 9, no. 2, pp. 109–114, 2022, doi: 10.24036/cived.v9i2.113909.

[13] J. Luo, T. Gao, and P. F. Yuan, "Fabrication of Reinforced 3D Concrete Printing Formwork," *Comput. Des. Robot. Fabr.*, vol. Part F1309, pp. 514–526, 2023, doi: 10.1007/978-981-19-8637-6_44.

[14] A. Perrot, Y. Jacquet, D. Rangeard, E. Courteille, and M. Sonebi, "Nailing of Layers: A Promising Way to Reinforce Concrete 3D Printing Structures," *Materials (Basel).*, vol. 13, no. 7, 2020, doi: 10.3390/ma13071518.

[15] D. Saptatiansah, "Analisis Perbandingan antara Pekerjaan Pemasangan Bekisting Konvensional Dengan Bekisting Aluminium Ditinjau Dari Segi Biaya Dan Waktu Pada Kolom," Universitas Islam Indonesia, 2021.

[16] S. Navaratnam, "Selecting a Suitable Sustainable Construction Method for Australian High-Rise Building: A Multi-Criteria Analysis," *Sustain.*, vol. 14, no. 12, 2022, doi: 10.3390/su14127435.

[17] J. Mata-Falcón *et al.*, "Digitally fabricated ribbed concrete floor slabs: a sustainable solution for construction," *RILEM Tech. Lett.*, vol. 7, pp. 68–78, 2022, doi: 10.21809/rilemtechlett.2022.161.

[18] W. Drozd, A. Leśniak, and S. Zaworski, "Construction Time of Three Wall Types Made of Locally Sourced Materials: A Comparative Study," *Adv. Mater. Sci. Eng.*, vol. 2018, pp. 1–8, 2018, doi: 10.1155/2018/2172575.

[19] R. Manju, R. Deepika, T. Gokulakrishnan, K. Srinithi, and M. I. Mohamed, "A Research on 3d Printing Concrete," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2 Special Issue 8, pp. 1691–1693, 2019, doi: 10.35940/ijrte.B1134.0882S819.

[20] S. Hayashi and T. Gondo, "Analysis of the construction of a reinforced-concrete free-form roof formwork and the development of a unit-construction method," *J. Build. Eng.*, vol. 34, no. September 2020, p. 101924, 2021, doi: 10.1016/j.jobe.2020.101924.

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

[21] I. Bagus, A. Wijaya, L. Djakfar, and S. P. Budio, “Studi Perbandingan Biaya Bekesting Semi Modern Dengan Bekesting Konvensional Pada Bangunan Gedung,” *J. Rekayasa Sipil*, vol. 6, no. 3, pp. 237–246, 2012.

[22] M. Hoffmann, K. Żarkiewicz, A. Zieliński, S. Skibicki, and Ł. Marchewka, “Foundation piles—a new feature for concrete 3d printers,” *Materials (Basel).*, vol. 14, no. 10, 2021, doi: 10.3390/ma14102545.

[23] Y. Yang *et al.*, “Performances of Concrete Columns with Modular UHPC Permanent Formworks Under Axial Load,” *Int. J. Concr. Struct. Mater.*, vol. 17, no. 1, pp. 1–14, 2023, doi: 10.1186/s40069-023-00608-1.

[24] Legstyana, “A Comparison on the Implementation Cost Coventional Formwork and Formwork With PERI System,” Sebelas Maret Surakarta, 2012.

[25] A. M. Trijeti, “Analisis Bekisting Metode Semi Sistem dan Metode Sistem Pada Bangunan Gedung,” *J. Konstr.*, vol. 4, no. 2, pp. 27–38, 2013.

[26] M. Arif and A. Irawan, “Evaluasi Penggunaan Bekisting Konvensional dan Sistem PERI ada Konstruksi CW Outfall Foundation Proyek PLTGU Muara Karang 400-500MW,” *J. Kaji. Tek. Sipil*, vol. 6, no. 1, pp. 9–19, 2021, doi: 10.52447/jkts.v6i1.4886.

[27] S. Biruk and P. Jaskowski, “Optimization of Vertical Formwork Layout Plans Using Mixed Integer Linear Programming,” *Int. J. Civ. Eng.*, vol. 15, no. 2, pp. 125–133, 2017, doi: 10.1007/s40999-016-0090-6.

[28] A. F. Saputra, F. Rahmawati, and Y. E. Putri, “Analisa Biaya dan Waktu Bekisting Metode Konvensional dengan Sistem PERI pada Proyek Puncak Kertajaya Apartemen,” *J. Tek. Sipil Inst. Teknol. Sepuluh Nop.*, pp. 1–6, 2013.

[29] Widia Ayu Noviantini, “Analisis Produktivitas Pekerjaan Bekisting Sistem PERI dan Konvensional Menggunakan Metode Webcyclone,” 2017.

[30] M. A. B. Efendi and R. G. Wibowo, “Pertimbangan Biaya dalam Pemilihan Bekisting,” *J. PILAR Teknol. J. Ilm. Ilmu Ilmu Tek.*, vol. 6, no. 2, pp. 69–75, 2022, doi: 10.33319/piltek.v6i2.101.

[31] S. Abramyan, V. Polyakov, and O. Oganesyan, “Pneumatic formwork used in strengthening of structural elements during reconstruction of buildings and structures,” *MATEC Web Conf.*, vol. 129, pp. 0–3, 2017, doi: 10.1051/matecconf/201712905001.

[32] V. Rajeshkumar, S. Anandaraj, V. Kavinkumar, and K. S. Elango, “Analysis of factors influencing formwork material selection in construction buildings,” *Mater. Today Proc.*, vol. 37, no. Part 2, pp. 880–885, 2020, doi: 10.1016/j.matpr.2020.06.044.