E-ISSN-2580-7129
Print- ISSN-1978-6107

TECHNO: JURNAL PENELITIAN
Journal homepage: http://ejournal.unkhair.ac.id/index.php/Techno
Volume 14 Number 01 May 2025 DOI: https://doi.org/10.33387/tjp.v14i1.10060

Efficiency Analysis of Time, Cost, and Labor between Conventional and Precast Sloof in Residential House

Nurlita Pertiwi[1*], Irma Aswani Ahmad[2]

[1] *Department of Building Engineering Education, Universitas Negeri Makassar, Indonesia, nurlita.pertiwi@unm.ac.id*
[2] *Department of of Building Engineering Education, Universitas Negeri Makassar, Indonesia, irma.aswani.ahmad@unm.ac.id*

Received : *11-03-2025*
Accepted : *02-05-2025*
Available online : *30-05-2025*

ABSTRACT

The growing demand for fast and efficient construction of low-income housing has driven innovations in construction execution methods. One emerging approach is the use of on-site precast sloof systems, which are cast and installed directly at the project site. This study aims to compare the efficiency of time, labor, and cost between conventional sloof and on-site precast sloof methods in small-scale housing developments. An experimental method was employed, utilizing eight repetitions for each method, with measurements encompassing execution time, labor requirements (both skilled and unskilled), and total costs. The results indicate that the precast method is more time-efficient, with a 13.83% reduction, and requires 22.1% less skilled labor. However, it also leads to a 40.5% increase in demand for unskilled labor. In terms of cost, the precast sloof method was 23% more expensive, with a cost-efficiency ratio of 1.23 compared to the conventional method. Nevertheless, the advantages in execution speed and reduced reliance on skilled workers make on-site precast sloof a strategic alternative for low-cost housing projects, especially in areas with limited skilled labor availability.

Keywords: Precast sloof, Time efficiency, Labor, Construction cost, Low-cost housing

ABSTRAK

Kebutuhan akan pembangunan rumah sederhana yang cepat dan efisien mendorong inovasi dalam metode pelaksanaan konstruksi. Salah satu pendekatan yang berkembang adalah penerapan sloof pracetak yang dicetak dan dipasang langsung di lokasi proyek. Penelitian ini bertujuan untuk membandingkan efisiensi waktu, tenaga kerja, dan biaya antara metode sloof konvensional dan sloof pracetak dalam proyek perumahan skala kecil. Metode yang digunakan bersifat eksperimental dengan delapan kali pengulangan untuk masing-masing metode, yang mencakup pengukuran waktu pelaksanaan, jumlah tenaga kerja (terampil dan tidak terampil), serta total biaya. Hasil penelitian menunjukkan bahwa metode pracetak lebih efisien dalam hal waktu, dengan penghematan sebesar 13,83%, dan memerlukan tenaga kerja terampil 22,1% lebih sedikit. Namun, kebutuhan tenaga kerja tidak terampil meningkat sebesar 40,5%. Dari sisi biaya, sloof pracetak memiliki nilai efisiensi 1,23 atau 23% lebih mahal dibandingkan metode konvensional. Meskipun demikian, keunggulan dalam kecepatan pelaksanaan dan pengurangan kebutuhan tenaga ahli menjadikan sloof pracetak sebagai alternatif strategis untuk pembangunan rumah sederhana, khususnya di wilayah dengan keterbatasan sumber daya terampil.

Kata kunci: Sloof pracetak, Efisiensi waktu, Tenaga kerja, Biaya konstruksi, Rumah sederhana

INTRODUCTION

The growing population in Indonesia has directly contributed to the increasing demand for decent housing. One manifestation of this trend is the continuous surge in demand for low-cost housing from year to year. According to data from the Ministry of Public Works and Public Housing, the estimated demand for low-cost housing in Indonesia reaches approximately 12.7 million units spread across all provinces. This situation requires the construction sector not only to deliver housing in large volumes but also to execute projects quickly and efficiently. As the demand for rapid and affordable housing construction increases, the industry faces the challenge of adopting more efficient methods in terms of time, labor, and cost. One approach that has attracted growing attention is the use of precast technology, particularly in basic structural elements such as sloof beams.

Previous studies have demonstrated several advantages of precast systems compared to conventional methods. The production stages of precast components can be optimized using data association approaches, resulting in higher productivity and lower costs (Chen et al., 2020). The variable-grade precast slabs provide excellent flexural performance and joint stiffness, while also facilitating faster field installation (Lv et al., 2023). In infrastructure projects, the ultra-thin reactive powder concrete precast slabs have been successfully applied to bridge beam joints, which significantly shortened the project duration by up to five months without increasing construction costs (Lan et al., 2024).

Other research results show that discretely connected precast floor systems maintain lateral stiffness without requiring additional in-situ casting, thus reducing dependence on skilled labor (Pang et al., 2020). The potential of lightweight post-tensioned precast panels, which are easier to install and reduce the need for complex support structures (Pedreschi, 2013). These findings are supported by other studies that report improved installation efficiency, higher labor productivity, and reduced environmental impact. The precast systems can shorten construction time without compromising quality, even when workforce availability is limited (Zhao et al., 2022). Continuous reinforcement in precast beam-column connections enhances productivity and streamlines execution processes (Alva et al., 2020).

Researchers have conducted a direct comparison between precast and cast-in-place systems, finding significant differences in labor and time efficiency (Septiarsilia et al., 2023). They concluded that precast systems are particularly suitable for low-cost housing projects, especially when integrated with on-site precasting. This approach not only reduces transportation costs but also offers greater flexibility in adapting to local resource availability. This finding is strengthened by the results of other research which shows that precast structures can meet strength and stability standards even in small-scale projects (Liu et al., 2021; Chandra et al., 2023).

From a cost-efficiency perspective, although the initial investment for precast systems may be higher, long-term savings in labor and material costs make the method more economical overall (Zheng et al., 2023). The hybrid precast connections in mid-rise buildings provide not only cost benefits but also reliable seismic performance (Chandra et al., 2023). Regarding sustainability, precast systems have the potential to reduce carbon emissions through more efficient material use and faster construction timelines, aligning with environmentally conscious building practices (Qi et al., 2024).

Nevertheless, most of these studies are focused on high-rise buildings, bridge structures, or large-scale infrastructure projects. There is still a lack of research that specifically evaluates the efficiency on-site precast systems in the context of low-cost housing. Moreover, few studies have examined time, labor (both skilled and unskilled), and cost aspects simultaneously in a comprehensive analysis.

To address this gap, the present study focuses on the application of on-site precast sloof systems, which are cast and installed directly at the project site. This method is considered more suitable for low- to middle-income housing developments, which typically face limitations in access to factory-produced precast elements. Therefore, this research aims to analyze the efficiency of execution time, labor requirements, and total cost for sloof installation using two different methods: conventional and on-site precast. The study focuses on small-scale housing projects, aiming to provide practical insights into the feasibility of using on-site precast systems in real-world conditions.

The novelty of this research lies in its comparative analysis, which not only evaluates execution speed but also considers the composition of labor-both skilled and unskilled, and the overall cost implications. Comprehensive studies that integrate all three efficiency aspects in the context of sloof work for small-scale projects remain limited in the Indonesian setting. As a result, the findings of this study are expected to offer clearer and more applicable guidance for housing contractors and construction practitioners in selecting sloof installation methods that are not only technically efficient but also suited to the realities of available on-site resources. Ultimately, this research supports the goal of achieving faster, more efficient, and economically feasible low-cost housing development.

METHODOLOGY

This study employs an experimental approach to measure and compare the efficiency of cost, time, and labor involved in the installation of conventional and on-site precast sloof systems in low-cost housing projects. Observations were conducted through eight repetitions for each installation method. For the conventional method, sloofs with varying lengths between 2.5 to 3.0 meters were observed. In contrast, the precast sloofs used in the study had a standardized span length of 7.0 meters and were cast and installed directly at the project site (on-site precasting). During each repetition, data were collected on the duration of execution, the number of laborers involved (both skilled and unskilled), and the total cost required to complete one meter of sloof. Efficiency for each aspect was calculated using the following formulas 1, 2 and 3. The calculated efficiency values were then analyzed to evaluate the potential of the precast method as a superior alternative to conventional methods in the context of small-scale residential development.

$$Cost\ Efficiency = \frac{Cost\ of\ precast\ sloof\ installation}{Cost\ of\ conventional\ sloof\ installation} \tag{1}$$

$$Time\ Efficiency = \frac{Time\ required\ of\ precast\ sloof\ installation}{Time\ required\ of\ conventional\ sloof\ installation} \tag{2}$$

$$Labor\ Efficiency = \frac{Number\ of\ workers\ for\ sloof\ installation}{Number\ of\ workers\ for\ conventional\ sloof\ installation} \tag{3}$$

RESULTS AND DISCUSSION

Stages of Sloof Construction

This study examined two types of sloof construction: conventional sloof and precast sloof. Each type involved a distinct sequence of implementation stages, as illustrated in Figure 1 and Figure 2. Figure 1 illustrates the typical process flow for conventional sloof installation, commonly used in simple housing projects. The process began with cutting Ø8 mm reinforcing steel bars, which served as the primary material for forming the stirrups. These bars were then bent into stirrup shapes according to the design specifications.

Subsequently, the primary reinforcement was assembled by combining the longitudinal bars and stirrups into a complete reinforcement cage. Simultaneously, another team prepared the formwork by cutting multiplex panels and timber supports. Once all materials were ready, the formwork assembly was carried out. The reinforcement was then placed into the installed formwork, followed by the concrete pouring process. After the concrete had reached the required curing time, the formwork was removed, revealing the completed sloof element. Each step was performed sequentially and in a coordinated manner to ensure construction quality and safety on site.

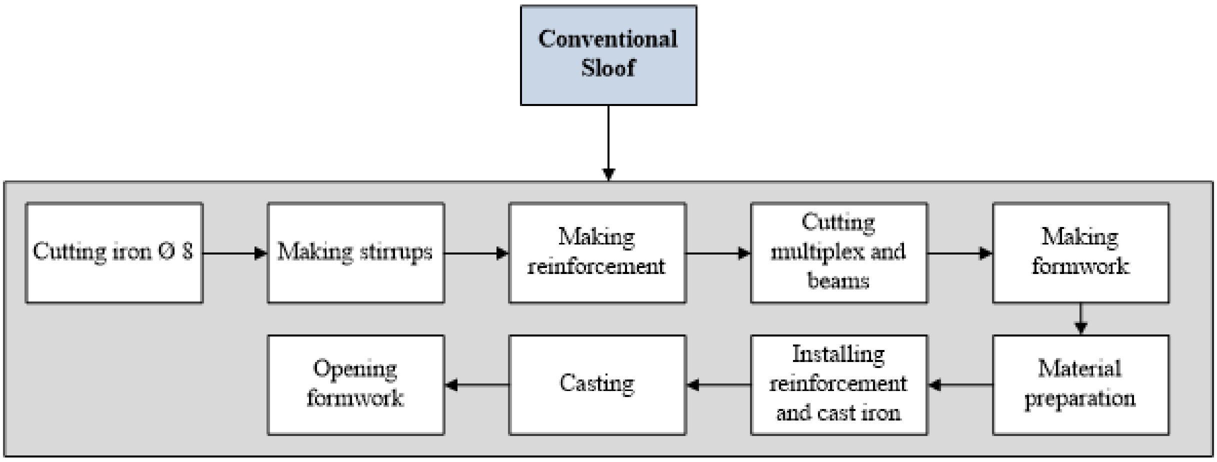

Figure 1. Conventional sloof jobs

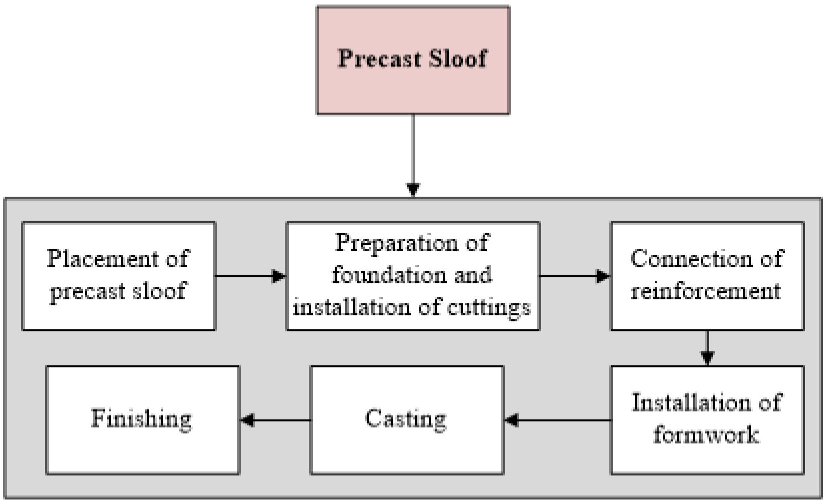

Figure 2. Precast sloof jobs

Figure 2 illustrates the stages of precast sloof construction, where the components are cast directly at the project site (on-site precasting). The process began with positioning the precast sloof elements in their designated locations according to the building plan. This stage required careful lifting and alignment to ensure that the sloof elements were accurately and stably positioned.

The next step involved preparing the foundation and installing the connection components, which included checking the elevation, placing support stands, and adjusting the sloof ends to accommodate the joints between elements. Afterward, the reinforcement was connected between the precast sloof and adjacent structural components to ensure structural continuity. This connection was established either through reinforcement pass-through systems or with additional connection materials.

Formwork was then installed at the joints and wet connections to maintain shape during the casting process. Once all joints were adequately prepared, concrete was poured into the joint areas to integrate the precast components into a monolithic structure. The final stage included finishing activities, such as removing the formwork, cleaning the work area, and preparing the sloof surface for subsequent construction work. This method offered greater time efficiency and improved work quality, as most structural processes had been completed prior to on-site installation.

Work Time Efficiency Analysis

Table 1 presents the observation results of conventional sloof installation times across varying lengths, ranging from 2.5 to 3.3 meters. The processing times were initially recorded in seconds, converted to hours, and then used to calculate the time coefficient per meter (in days per meter).

Table 1. Observation of conventional sloof job time

Length (Meters)	3	2.5	3.3	2.8	2.5	3	2.8	3
Processing Time (Seconds)	3437	2866	2848	2863	3033	3109	3036	2718
Operating Time (Hours)	0.119	0.100	0.099	0.099	0.105	0.108	0.105	0.094
Conventional Sloof Work Time Coefficient (Days/Meter)	0.040	0.040	0.030	0.036	0.042	0.036	0.038	0.031

This time coefficient reflects the actual time required to complete a sloof segment, normalized by its length. The recorded processing times ranged from 2,718 to 3,437 seconds, with an average time coefficient of approximately 0.037 days per meter. The highest coefficient, 0.042 days/meter, was recorded at a length of 2.5 meters, while the lowest, 0.030 days/meter, occurred at a length of 3.3 meters. These variations suggest that both the sloof length and the efficiency of the field team significantly influenced the duration of the work.

Meanwhile, Table 2 shows the observation results for precast sloof installations, each with a fixed length of 6 meters. The installation times ranged from 4,499 to 7,108.6 seconds, which were then converted into hours and further processed to determine the coefficient of work time per meter. The time coefficients for precast sloof ranged from 0.026 to 0.041 days/meter, with an average of 0.031 days/meter. These values are consistently lower than those of the conventional method, indicating that the precast approach offers better time efficiency. The variation in observations was likely due to differences in site conditions and the readiness of installation teams. A direct comparison between Table 1 and Table 2 highlights a noticeable gap in time performance between the two construction methods. The conventional method showed an average coefficient of 0.037 days/meter, while the precast method recorded 0.031 days/meter. Although the numerical difference may appear small, it can result in substantial savings on larger-scale housing projects.

Table 2. Observation of conventional sloof job time

Length (Meters)	Panjang (meter)	6	6	6	6	6
Processing Time (Seconds)	Work Time (Seconds)	4715	5416	4499	5464	7108.6
Operating Time (Hours)	Work Time (Hours)	0.164	0.188	0.156	0.190	0.247
Conventional Sloof Work Time Coefficient (Days/Meter)	Conventional Sloof Work Time Coefficient (Days/Meters)	0.027	0.031	0.026	0.032	0.041

The precast method also exhibited more consistent time performance, likely due to the uniform 6-meter sloof segments used. This consistency simplifies work scheduling and resource allocation. In contrast, the conventional method showed higher variability in duration, influenced by factors such as inconsistent sloof lengths, reliance on on-site concrete mixing, and varying worker productivity. To quantify the efficiency advantage, a time efficiency calculation was performed using the average values.

$$Time\ Efficency = \frac{0.031}{0.037} x\ 100\% = 86.17\ \%$$

This result implies that precast sloof installation required only 86.17% of the time needed for the conventional method, equating to a time saving of approximately 13.83%. While the per-meter difference may seem minor, when applied to housing blocks or full residential developments, the cumulative time savings become highly significant. In conclusion, based on the observations, the use of precast sloof demonstrates clear advantages in terms of execution speed. It also offers more consistent durations, which are crucial for efficient project scheduling and labor management. These advantages support the adoption of precast sloof as a practical and efficient alternative for small-scale housing developments.

Labor Efficiency Analysis

Labor efficiency analysis was divided into two parts according to labor competencies. The first part involves skilled labor, which had a high level of mastery in applying sloof work to both precast sloof and conventional sloof. Meanwhile, untrained workers were workers who need assistance during the implementation of sloof work. This analysis utilizes data on the observation of sloof work time, followed by the calculation of the coefficients for skilled and unskilled workers at each stage of work. The calculation of the number of workers were carried out by multiplying the labor coefficient by the work time.

Table 3 presents the coefficient of labor needs in the implementation of precast sloof based on the type of work and skill classification. From the table, it can be seen that precast sloof work was dominated by activities that require unskilled labor, such as the placement of precast elements, the preparation of foundations, and the installation of cuttings, as well as the connection of reinforcements. The highest coefficient value for unskilled labor was recorded in the reinforcement connection activity, at 0.091, followed by precast placement and foundation preparation, with values of 0.086 and 0.082, respectively. On the other hand, skilled labor was needed more at the technical stage, such as reinforcement connection (0.045), precast placement (0.043), and foundation preparation (0.041). Overall, the total coefficient for skilled labor was 0.167, while the coefficient for unskilled labor was 0.371. This result indicates that precast systems tend to reduce the need for skilled workers, but increase the intensity of unskilled labor in support activities and field installations.

Table 3. Labor coefficient on precast sloof jobs

Work	Skilled labor coefficient	Unskilled labor coefficient
Precast sloof placement	0.043	0.086
Foundation preparation and installation of cuttings	0.041	0.082
Reinforcement connection	0.045	0.091
Installation of the squirrel	0	0.007
Casting	0.037	0.075
Finishing	0	0.031
Total	0.167	0.371

Table 4. Labor coefficient in conventional sloof jobs

Activity	Skilled labor coefficient	Unskilled labor coefficient
Reinforcement cutting Ø 8	0.005	0
Manufacture of begels	0.004	0
Reinforcement manufacturing	0.004	0.004
Cutting multiplexes and beams	0.004	0.004
Formwork manufacturing	0.004	0.004
Material preparation	0	0.009
Reinforcement and formwork installation	0.003	0.003
Casting	0.012	0.018
Formwork opening	0	0.003
Average	0.036	0.044

On the other hand, Table 4 shows the distribution of labor coefficients in the implementation of sloof using conventional methods. The need for skilled labor was relatively evenly distributed at almost all stages of work, including cutting Ø 8 bar, making beads and reinforcements, cutting formwork materials, and casting processes. The most considerable coefficient value for skilled labor was recorded in the casting process (0.012), while the highest coefficient value for unskilled labor was also in the casting process (0.018), indicating that this process involves cross-skill collaboration. The total coefficient of skilled labor in the conventional method is 0.214, while the unskilled labor is 0.264. When compared to precast systems, conventional methods tend to require more skilled labor but involve less unskilled labor. The analysis of the efficiency of skilled labor in conventional sloof work, using labor coefficient data from Table 4, yielded a value of 0.036. So, for a length of 6 meters, 0.036 x 6 is 0.214. As for the precast sloof, it is taken from Table 3, which is 0.167, so the calculation of the efficiency of skilled work can be determined.

$$Efficiency\ of\ skilled\ labor = \frac{0{,}167}{0{,}214} = 0{,}779$$

The results of the time efficiency calculation in the formula above show that the installation time of a precast sloof was more efficient compared to the manufacturing time of a conventional sloof. A time efficiency value of 0.779 means that the installation time of *the precast Sloof* was only 77.9% of the time required for the manufacture of a conventional *sloof*. In other words, *precast sloof* can save about 22.1% of the time required for conventional methods.

Furthermore, for the efficiency of unskilled labor in conventional sloof work, the labor coefficient was taken from Table 4, which is 0.044. So, for a length of 6 meters, 0.036 x 6 was 0.216. As for the precast sloof, it was taken from Table 3, which was 0.371, so the calculation of skilled labor efficiency can be determined.

$$Efficiency\ of\ unskilled\ labor\ = \frac{0{,}371}{0{,}264} = 1{,}405$$

The results of the calculation of the efficiency of the amount of unskilled labor in the above formula show that the installation *of precast sloof required more unskilled labor compared to the manufacture of conventional sloofs*. An efficiency value of 1.405 indicates that the amount of unskilled labor required for the installation of a Precast sloof is 40.5% higher than the base value. The use of precast in construction has shown significant labor efficiency compared to conventional concrete methods. Several studies have been conducted to compare labor efficiency between these two methods. The use of precast concrete composite structure members in the construction of columns and beams can reduce the amount of labor required on the construction site.

Cost Efficiency Analysis

Cost efficiency analysis refers to the unit price of labor, the price of the unit of materials, and the processing time. Descriptions of cost analysis data needs are presented in Tables 5, 6, and 7.

Table 5. Precast sloof installation labor unit price analysis

Types of Labor	Coefficient	Unit Price (IDR)	Total (IDR)
Skilled Labor	0.167	150,000	25,020.833
Unskilled Labor	0.371	100,000	37,101.111
	Total Price (IDR)		62,121.944

Table 6. Precast sloof installation unit price analysis

Materials	Unit	Volume	Unit Price (IDR)	Total Price (IDR)
Fine Aggregate	m3	0.018129086	42,260.00	76,613.5162
Course Aggregate	m3	0.02856	385,000	10,995.6
Cement	zak	0.374	65,000	24,310
Water	m3	13.7484	13,600	186,978.24
Reinforcement Ø 6	kg	0.444	385,000	170,940
Multiplex	m3	0.32	70,000	22,400
Formwork Nail	kg	0.01	18,800	188
		Total		492,425
		Total 6 meter		554,547

Table 7 shows the recapitulation results of the cost of precast sloof. Previously, the cost of the precast sloof was calculated in detail at IDR 416,038, investment of IDR 180,750 and the installation of precast sloof on the foundation of IDR 554,547, totaling IDR 1,151,335. Table 8 shows that the calculation of the cost of conventional sloof work also begins with the analysis of the labor coefficient.

Table 7. Total cost of six meters long precast sloof

Indicator	Cost
Precast sloof (5 beams)	416,038.0164
Investigation of Precast sloof (beams)	180,750
Precast sloof Installation 5 Buah	554,547
Total	1,151.335

Table 8. Labor coefficient in conventional sloof jobs

Activity	Skilled labor coefficient	Unskilled labor coefficient
Reinforcement cutting Ø 8	0.005	0
Manufacture of begels	0.004	0
Reinforcement manufacturing	0.004	0.004
Cutting multiplexes and beams	0.004	0.004
Formwork manufacturing	0.004	0.004
Material preparation	0	0.009
Reinforcement and formwork installation	0.003	0.003
Casting	0.012	0.018
Formwork opening	0	0.003
Average	0.036	0.044

Table 9 shows that the calculation of the cost of conventional sloof work also uses material costs. The table 10 also the total cost analysis are then used to calculate the total cost of conventional sloof work.

Table 9. Cost of conventional sloof work materials

Materials	Unit	Volume	Unit Price (IDR)	Total Price (IDR)
Reinforcement Ø 6	kg	0.091	14,250	1299,6
Reinforcement Ø 8	kg	1.896	14,250	27,018
Fine Aggregate	m^3	0.020	422,600	8,452
Cement	zak	0.330	65,000	21,450
Course Aggregate	m^3	0.032	385,000	12,284,739
Water	m^3	0.001	13,600	10,983.36
Wire	kg	0.083	18,800	1,567
Multiplex	piece	0.220	116,700	25,674
5/7 Timber	m^3	0.005	10,000.000	46,667
Formwork Nail	kg	0.067	15,000	1,000
		Total		145,706

Table 10. Total cost of materials and labor on a conventional sloof job

Types of Labor	Coefficient	Unit Price (IDR)	Total (IDR)
Skilled Labor	0.035	150,000	5,354,249
Unskilled Labor	0.044	100,000	4,432,581
Total Price (IDR)			9,786,831
Total materials and labor per meter (IDR)			155.493

The results of the cost efficiency calculation using the above formula show that the cost of a precast sloof was higher than the cost of a conventional sloof. The cost efficiency value was 1.23, which means that the cost of precast Sloof is 23% more expensive than conventional *sloof*.

$$Cost\ Efficency = \frac{1.151.335}{932.957} = 1.23$$

The result shows that using a precast sloof was more expensive compared to a conventional sloof. However, it is essential to note that this cost efficiency may not account for other factors, such as improved work management and achieving time efficiency. The use of precast sloof in the construction industry has opportunities due to the cost efficiency and work environment advantages it offers compared to conventional concrete. Precast concrete, which is manufactured in a factory and then installed on-site, has several significant advantages, including reduced construction time, reduced waste, and improved quality control (Othman et al., 2017; Špak et al., 2016).

One study showed that the use of precast concrete can reduce construction costs by up to 20-30% compared to conventional methods (Yee, 2011). This result is due to the reduction in on-site labor requirements, resulting from the numerous processes carried out in the plant, as well as the decrease in curing time required for conventional concrete (Xu et al., 2017). In addition, precast concrete also offers advantages in terms of earthquake resistance and better structural quality, which can reduce maintenance costs in the future (Kurama et al., 2018).

Precast concrete sandwich panels (PCSPs) also show significant cost efficiency. These panels not only provide sound thermal insulation but also reduce maintenance costs due to the material's higher durability. Research indicates that the use of PCSPs can reduce operational energy costs by up to 30%, resulting in long-term savings (Tawil et al., 2022). In terms of environmental impact, the use of precast concrete supports sustainable development practices. Standardized production processes and efficient use of materials help reduce the carbon footprint of construction projects (Nurjaman et al., 2022).

CONCLUSION

The results of this study show that the conventional sloof installation method requires a longer implementation time compared to the precast method. Precast sloofs provide a time efficiency of 13.83%, which can significantly speed up the construction process. In terms of labor needs, the precast method requires less skilled labor, with an efficiency of 22.1%. However, the need for unskilled labor has increased by 40.5% compared to conventional methods. On the cost side, the precast sloof showed an efficiency value of 1.23, indicating that the execution cost was 23% higher than that of the conventional method. By considering these three aspects, it can be concluded that the implementation of precast sloof is more advantageous in terms of implementation time and efficiency of skilled labor allocation. However, this method still has weaknesses in terms of financing. Therefore, precast sloof is recommended for housing projects that prioritize accelerating time and labor efficiency, especially in areas with limited skilled labor, noting the need for more optimal cost management.

ACKNOWLEDGEMENTS

We would like to thank all parties who have helped with this research, especially the students who were involved in the data collection process for this research.

REFERENCES

Alva, G. M. S., Lacerda, M. M. S., & SILVA, T. (2020). Experimental study on precast beam-column connections with continuity reinforcement for negative bending moments. *Revista IBRACON de Estruturas e Materiais*, *13*(02), 314-347. https://doi.org/10.1590/S1983-41952020000200008.

Chandra, J., Lokito, V. N., & Tambuna, J. A. (2023). Seismic Performance of Precast Concrete Special Moment Frames with Hybrid Connection System in Five and Ten Story Buildings. *Civil Engineering Dimension*, *25*(2), 85-95. https://doi.org/10.9744/ced.25.2.85-95.

Chen, J. H., Hsu, S. C., Chen, C. L., Tai, H. W., & Wu, T. H. (2020). Exploring the association rules of work activities for producing precast components. *Automation in construction*, *111*, 103059. https://doi.org/10.1016/j.autcon.2019.103059.

Kurama, Y. C., Sritharan, S., Fleischman, R. B., Restrepo, J. I., Henry, R. S., Cleland, N. M., ... & Bonelli, P. (2018). Seismic-resistant precast concrete structures: State of the art. *Journal of Structural Engineering*, *144*(4), 03118001. https://doi.org/10.1061/(ASCE)ST.1943-541X.0001972.

Lan, J., Dai, J., Jia, B., Yan, Q., & Yang, Z. (2024). Experimental Study on the Mechanical Properties of Reactive Powder Concrete Ultra-Thin Precast Slab for Bridge I-Beam Joints. *Buildings*, *14*(12), 3977. https://doi.org/10.3390/buildings14123977.

Liu, Y. L., Huang, J. Q., Chong, X., & Ye, X. G. (2021). Experimental investigation on flexural performance of semi-precast reinforced concrete one-way slab with joint. *Structural Concrete*, *22*(4), 2243-2257. https://doi.org/10.1002/suco.202000676.

Lv, X., Yu, Z., & Liao, Z. (2023). Experimental study on flexural behavior of a novel variable-grade prefabricated concrete slab with surrounding composited. *Structural Concrete*, *24*(1), 892-905. https://doi.org/10.1002/suco.202100836.

Nurjaman, H., Suwito, S., Dinariana, D., Gambiro, S., Budiono, B., & Fau, M. (2022). Development of Numerical Model of a High Performance Precast Concrete System Equipped with Base Isolation. *Evergreen*, *9*(2), 547-555. https://doi.org/10.5109/4794186.

Othman, M. K. F., Muhammad, W. M. N. W., Abd Hadi, N., & Azman, M. A. (2017). The significance of coordination for Industrialised Building System (IBS) precast concrete in construction industry. In *MATEC Web of Conferences* (Vol. 103, p. 03004). EDP Sciences. https://doi.org/10.1051/matecconf/201710303004.

Pang, R., Xu, Z., Liang, S., Zhu, X., & Hu, K. (2020). Experimental and analytical investigation on the in-plane mechanical property of discretely connected precast RC floor diaphragm. *Journal of Building Engineering*, *32*, 101819. https://doi.org/10.1016/j.jobe.2020.101819.

Pedreschi, R. (2013). A feasibility study of post-tensioned stone for cladding. *Construction and Building Materials*, *43*, 225-232. https://doi.org/10.1016/j.conbuildmat.2013.02.008.

Qi, L., Ma, M., Chen, Y., Liao, X., Hua, J., Liu, Y., ... & Lu, L. (2024). Experimental study on the seismic behavior of a novel type of precast column-steel beam connection with grouted corrugated metallic duct. *Structural Concrete*, *25*(6), 5108-5138. https://doi.org/10.1002/suco.202300664.

Septiarsilia, Y., Iranata, D., & Suswanto, B. (2023). Hybrid Beam-Column Connection of Precast Concrete Structures: A Review. In *E3S Web of Conferences* (Vol. 434, p. 02019). EDP Sciences. https://doi.org/10.1051/e3sconf/202343402019.

Špak, M., Kozlovská, M., Struková, Z., & Bašková, R. (2016). Comparison of conventional and advanced concrete technologies in terms of construction efficiency. *Advances in Materials Science and Engineering*, *2016*(1), 1903729. https://doi.org/10.1155/2016/1903729.

Tawil, H., Tan, C. G., Sulong, N. H. R., Nazri, F. M., Sherif, M. M., & El-Shafie, A. (2022). Mechanical and thermal properties of composite precast concrete sandwich panels: A Review. *Buildings*, *12*(9), 1429. https://doi.org/10.3390/buildings12091429.

Xu, L., Pan, J., Leung, C. K. Y., & Yin, W. (2018). Shaking table tests on precast reinforced concrete and engineered cementitious composite/reinforced concrete composite frames. *Advances in Structural Engineering*, *21*(6), 824-837. https://doi.org/10.1177/1369433217733759.

Yee, P. T. L., Adnan, A. B., Mirasa, A. K., & Rahman, A. B. A. (2011). Performance of IBS precast concrete beam-column connections under earthquake effects: a literature review. *American Journal of Engineering and Applied Sciences*, *4*(1), 93-101. http://dx.doi.org/10.3844/ajeassp.2011.93.101.

Zhao, J., Li, F., & Chen, Z. (2022). Modeling coarse aggregate distribution in interfacial zone of new–old concrete in precast concrete structures. *Structural Concrete*, *23*(6), 3916-3928. https://doi.org/10.1002/suco.202100848.

Zheng, J., Pan, Z., Zhen, H., Deng, X., Zheng, C., Qiu, Z., ... & Liu, F. (2023). Experimental Investigation on the Seismic Behavior of Precast Concrete Beam-Column Joints with Five-Spiral Stirrups. *Buildings*, *13*(9), 2357. https://doi.org/10.3390/buildings13092357.