2026, Volume 06, No 01, pp.37-48, p-ISSN 2807-9450 e-ISSN 2808-4284

Jurnal Pendidikan Teknik Bangunan

Journal homepage: https://ejournal.upi.edu/index.php/JPTB

A Comparison of Sandwich Panels and Lightweight Bricks for an Eight-Story Lecture Building in Terms of Quality, Cost, and Time

Risha Helina[1*] , *Nemesius Bambang Revantoro*[2]

[1,2] Civil Engineering and Building Maintenance Technology, Universitas Negeri Malang, Malang, Indonesia

[1*]risha.helina.2205227@students.um.ac.id, [2]nemesius.bambang.ft@um.ac.id

ABSTRACT

Advances in construction technology have spurred the emergence of various building material innovations capable of improving project efficiency. In the construction industry, wall work is a critical element in the construction of multi-story buildings and has a significant impact on project duration and indirect costs. Although lightweight brick walls remain widely used due to their relatively low weight, this material requires finishing processes such as plastering and painting, which ultimately extend work time and increase overhead costs. As an alternative, EPS (Expanded Polystyrene) sandwich panels allow for faster installation without requiring additional finishing. This study was conducted to analyze the comparison of quality, cost, and time between sandwich panel walls and lightweight brick walls in an eight-story university building project. By applying a comparative quantitative method using primary data obtained through a case study project and secondary data from supporting literature, data processing was performed to estimate total project costs, project duration, and evaluate material quality based on technical specifications. The results show that sandwich panel walls have advantages in terms of quality and time, despite higher material costs compared to lightweight brick walls. This acceleration has the potential to significantly reduce overhead costs, thereby improving overall project efficiency.

ARTICLE INFO

Article History:

Submitted 24 Febuary 2026

First Revised 17 April 2026

Accepted 26 April 2026

Available Online 30 April 2026

Publication Date 30 April 2026

Keywords:

EPS Sandwich Panel; Lightweight Brick; Quality Cost Time; Wall

1. INTRODUCTION

The growth of global construction activity has led to a significant increase in the demand for building materials (Lakshmikandhan et al., 2017). The selection of materials in sustainable construction plays a crucial role in minimizing negative environmental impacts, conserving energy, and improving resource efficiency. One of the key components in construction work is the use of appropriate wall materials. Wall materials are a critical component found in nearly every building and encompass a significant portion of the work. When selecting wall materials, various factors must be considered, such as wall characteristics, installation methods, total costs, and time efficiency (Hidayat, 2018). Innovations in construction materials offer various alternatives that have the potential to enhance building performance, including sandwich panels, which are known for their superior thermal efficiency and installation speed compared to lightweight bricks (Mohamed et al., 2023). This material consists of an Expanded Polystyrene (EPS) core sandwiched between two surface layers of pre-painted galvanized steel.

In addition to affecting construction efficiency, the selection of wall materials also impacts the magnitude of a building's dead load. In materials mechanics, it is explained that dead load is one of the loading components that influences internal forces and stresses in structural elements such as columns, beams, and foundations (One et al., 2025). The use of lighter-weight wall materials, such as EPS sandwich panels, can theoretically reduce the loads acting on the building structure. This reduction in load has the potential to lower the required capacity and dimensions of primary structural elements, which in turn can improve the efficiency of structural material usage and reduce overall construction costs.

Several studies indicate that the use of EPS can reduce construction costs and time due to prefabrication and minimized material usage (Kumar et al., 2024; Silva et al., 2024) while others emphasize higher initial costs offset by long-term energy savings and faster construction times (Dhaif & Stephan, 2021; Hapsari et al., 2023; Iwan Christianto, 2024). Different results have also emerged regarding performance and structural durability, with certain studies highlighting superior thermal resistance, increased compressive strength, and carbon reduction achieved through the use of EPS panels (Busher & Varatharajapuram Govindarajulu, 2023; Maryani et al., 2019; Mohamed et al., 2023; Pratiwi et al., 2020) .

Research on the use of sandwich panels has been conducted on university building projects, one of which is the FPEB building at the Indonesia University of Education (UPI) (Setyawan & Pakpahan, 2024). These studies provide an initial overview of the application of sandwich panels in educational buildings. However, most of these studies still focus on aspects of strength or cost and time efficiency separately. Therefore, the novelty of this research lies in the interrelation between quality, cost, and construction time within a single analysis. This study aims (Fauzie & Wibowo, 2024) to analyze and compare the performance of EPS sandwich panels with lightweight bricks, focusing on three main aspects: material quality, total cost, and construction duration. This analysis used a comparative quantitative method, based on case study project data and supporting literature.

The limitations of this study include the exclusion of the structural characteristics of the entire building, analysis of overhead costs, or assessment of environmental factors. Instead, the study focuses solely on comparing the two types of wall materials—sandwich panels and lightweight bricks—in terms of quality, cost, and time. This study was conducted on an eight-story lecture hall construction project as a case study, with the research object being non-structural interior wall work, namely lightweight brick walls and EPS sandwich panel walls. It discusses the characteristics of each material, the results of the work quality analysis, a comparison of costs and construction duration, as well as their impact on the overall project efficiency.

2. METHOD

This research flowchart was created to provide an overview of the stages involved in the research process. The research flowchart in **Figure 1** illustrates the overall sequence of research activities, starting from the initial stage until conclusions are reached.

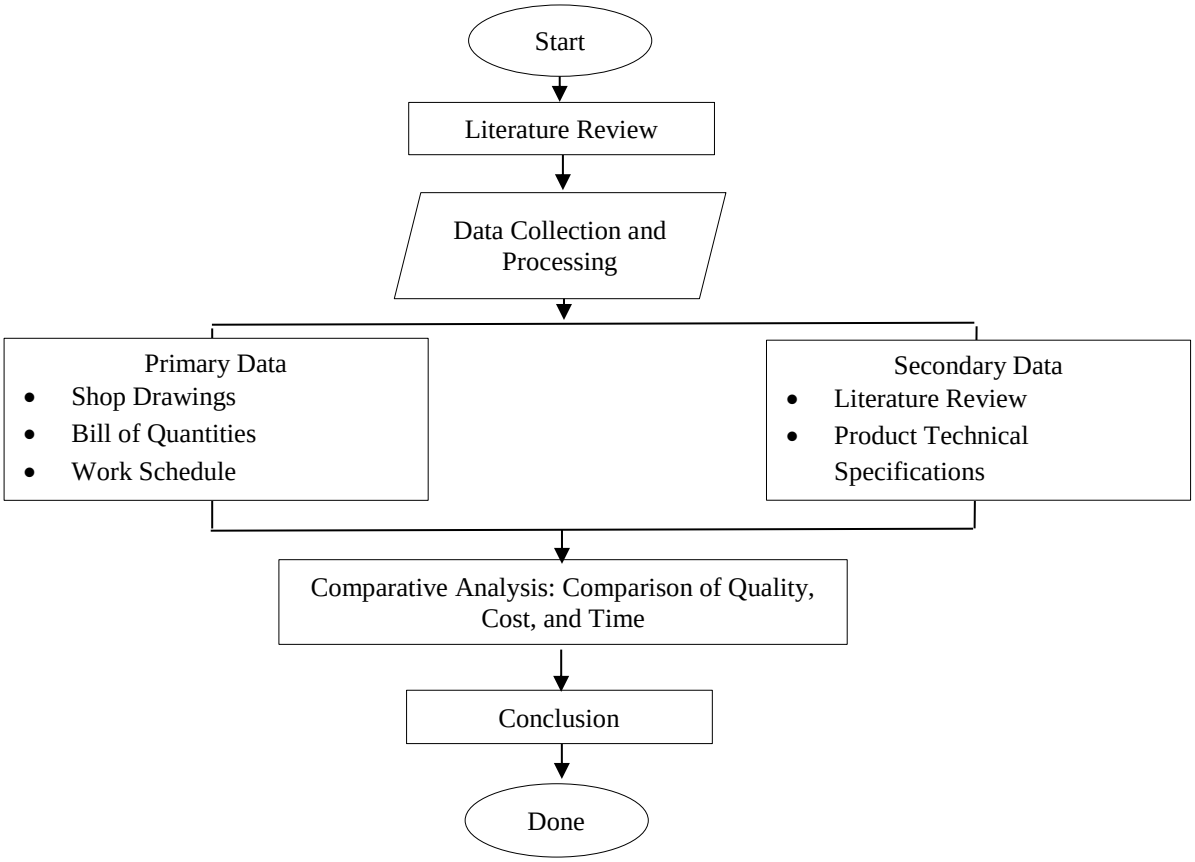

Figure 1. Research Flowchart

Based on **Figure 1**, the study began with a literature review to establish a theoretical foundation and identify relevant references. This was followed by the collection and processing of data, consisting of primary and secondary data. The data obtained were then analyzed comparatively by comparing the quality, cost, and time aspects of sandwich panel walls and lightweight brick walls. The final stage concludes based on the results of the analysis that has been carried out.

2.1 Data Collection

This research design employs a comparative quantitative approach. This study consists of two variables. The population serving as the subject of this research encompasses all wall construction work on an eight-story lecture building. This accounts for the equivalence of work conditions, volume, and installation area. The total sample area for each type of material is approximately 5,836.5 m^2. The research instruments were obtained directly from the eight-story lecture hall case study project, namely project documents covering the volume of work, unit prices for materials and labor, the number of workers, and the duration of execution. Technical material specifications and supporting literature from previous studies were also utilized. Cost and duration calculations were performed using Microsoft Excel based on the cost budget plan and productivity data from AHSP.

The material used in this study is an EPS (Expanded Polystyrene) sandwich panel with a thickness of 100 mm, a weight of 12 kg/m^2, and an EPS core with a density of 15 kg/m^3. The selection of these specifications is based on the common use of wall panels in multi-story buildings and refers to the technical specifications of manufacturer products widely used in the field. Meanwhile, the lightweight bricks (Autoclaved Aerated Concrete) used measure 600 x 200 x 100 mm with a specific gravity of 600 kg/m^3. These dimensions were chosen because they are standard sizes commonly used in masonry work.

2.2 Data Processing Techniques

The research was conducted in three stages, begenning with data collection from the case study project. The second stage involved collecting material data from technical documents and literature. The third stage involved analyzing and comparing the data, considering three main aspects: quality, total project cost, and construction duration. Data processing was conducted quantitatively by calculating and comparing total project costs based on volume and unit prices; the duration of implementation was calculated using the Unit Price Analysis Coefficient (AHSP) in accordance with Ministry of Public Works and People's Housing Regulation No. 1 of 2023 on Construction Work Unit Prices, Basic Unit Prices for Building Materials and Labor. Meanwhile, the basic unit prices used in the cost calculations refer to the Surakarta city regional unit price standards (Dinas PU Bina Marga dan Cipta Karya Provinsi Jawa Tengah, 2023) . Additionally, quality analysis is based on each material's specifications, with results presented in tables and graphs.

2.3 Quality Analysis

In this study, quality aspects were not directly tested in a laboratory but were derived from the materials' technical specifications and supporting literature, including results from previous studies. Subsequently, quality data were conceptually compared to assess the relative advantages of the materials.

2.4 Cost Analysis (CA)

The cost analysis was conducted using the unit price per square meter for each task, which was then used to calculate the total cost of the entire project. The cost analysis calculation is based on the following equation:

$$CA = Volume \times Unit\ Price\ of\ Work$$

(Ajar & Dofir, 2021)

2.5 Productivity Analysis (PA)

The productivity analysis covers the materials, workers, and tools used. Daily productivity is calculated based on the following equation:

$$PA = \frac{v}{n \times T}$$

(Husain et al., 2022)

PA = productivity
v = work volume
n = number of workers
T = duration

2.6 Time Analysis

Time analysis is influenced by various factors, including the volume of work, the tools used, and labor productivity. The duration of the work is calculated using the following equation:

$$Duration = \frac{volume\ of\ work}{number\ of\ workers \times productivity}$$

(Choirul Effendi & Pandulu, 2020)

3. RESULT AND DISCUSSION

The results of this study were obtained through data processing, which was then analyzed to compare the performance of sandwich panel walls and lightweight brick walls. The comparison was conducted comprehensively, taking into account quality, cost, and time. It was carried out in stages to highlight the differences in the characteristics of each material based on these three aspects.

3.1 Material Quality

This comparison of material quality will explore several aspects to provide a comprehensive understanding of its quality. The comparison of each material quality can be seen in **Table 1.**

Table 1. Comparison of the Quality of EPS Sandwich Panels and Lightweight Bricks

Quality	EPS Sandwich Panels	Lightweight Brick
Density	Light (15 kg/m³)	Heavier (600 kg/m³)
Thermal Insulation	Low thermal conductivity (0.038 W/mK)	Higher thermal conductivity value (0.19 W/mK)
Durability	Water absotion of approximately ≤2% with temperature resistance of -40°C to +90°C	Water absotion 5–10% with higher temperature resistance

Quality	EPS Sandwich Panels	Lightweight Brick
Compressive Strength	0.62 MPa	4 MPa
Fire Resistance	Self-extinguishing fire resistance	Fire-resistant up to 1,000 °C
Architectural Features	Smooth surface with galvanized steel coating and anti-corrosion paint; design variations are limited to factory specifications.	Easy to shape, cut, and customize to architectural specifications.

Based on **Table 1**, a comparison of the quality between EPS sandwich panels and lightweight bricks reveals distinct performance characteristics. In projects using EPS sandwich panels, quality is evident in their lighter weight and the uniformity of panel shapes produced in a factory setting. This results in a neater and more stable final wall quality. EPS sandwich panels provide superior thermal insulation compared to lightweight bricks because the core material in EPS sandwich panels reduces temperature gradients in walls, improving a building's energy efficiency (Thangarasu & Henderson, 2022) .

EPS sandwich panels are resistant to humid environments and temperature fluctuations because the panel surfaces are sealed and do not absorb water. Although their compressive strength is relatively lower than that of lightweight brick, this material possesses sufficient strength for non-structural wall applications. Regarding fire resistance, EPS sandwich panels typically feature a core with self-extinguishing properties; however, they still require additional protection in accordance with fire safety standards. Conversely, lightweight bricks require a protective coating to prevent water absotion, which can affect their long-term performance, but they offer the advantage of higher compressive strength and better fire resistance.

3.2 Project Costs

The total project cost is influenced by material costs, labor wages, and equipment prices (Maulana et al., 2024) . The results of the total cost analysis required for an eight-story lecture building using EPS sandwich panel walls and lightweight brick walls are listed in **Table 2** and **Table 3.**

Table 2. Cost Estimate for EPS Sandwich Panel Walls

No	Work Description	Volume	Unit	Unit Price	Total Price
A	1st Floor (Elev. 0.000)				
	EPS Sandwich Panel	949.5	m^2	IDR 650,599.62	IDR 617,744,340.95
B	2nd Floor (Elev. +4,500)				
	EPS Sandwich Panel	1053	m^2	IDR 650,599.62	IDR 685,081.40181
C	3rd Floor (Elev. +9,000)				
	EPS Sandwich Panel	787.5	m^2	IDR 650,599.62	IDR 512,347,202.21
D	4th Floor (Elev. +13,500)				
	EPS Sandwich Panel	832.5	m^2	IDR 650,599.62	IDR 541,624,185.19
E	5th Floor (Elev. +18,000)				
	EPS Sandwich Panel	643.5	m^2	IDR 650,599.62	IDR 418,660,856.66

No	Work Description	Volume	Unit	Unit Price	Total Price
F	6th Floor (Elev. +22,500)				
	EPS Sandwich Panel	706.5	m²	IDR 650,599.62	IDR 459,648,632.84
G	7th Floor (Elev. +27,000)				
	EPS Sandwich Panel	864	m²	IDR 650,599.62	IDR 562,118,073.28
		Total EPS Sandwich Panel Wall Work			**IDR 3,797,225,000.00**

Table 3. Cost Estimate for Lightweight Brick Wall Work

No	Work Description	Volume	Unit	Unit Price	Total Price
A	1st Floor (Elev. 0.000)				
	Lightweight Brick Wall Panels 600 x 200 100 mm	949.5	m²	IDR 154,303.99	IDR 146,511,634.80
	Plaster	1899	m²	IDR 59,927.89	IDR 113,803.06
	Plastering	1899	m²	IDR 36,158.16	IDR 68,664.33
	Wall Paint	1899	m²	IDR 55,269.50	IDR 104,956.78
B	2nd Floor (Elev. +4,500)				
	Lightweight Brick Wall 600 x 200 100 mm	1053	m²	IDR 154,303.99	IDR 162,482,097.36
	Plaster	2106	m²	IDR 59,927.89	IDR 126,208.136
	Plastering	2106	m²	IDR 36,158.16	IDR 76,149.07
	Wall Paint	2106	m²	IDR 55,269.50	IDR 116,397.56
C	3rd Floor (Elev. +9,000)				
	Lightweight Brick Wall 600 x 200 100 mm	787.5	m²	IDR 154,303.99	IDR 121,514.38905
	Plaster	1575	m²	IDR 59,927.89	IDR 94,386.42
	Plastering	1575	m²	IDR 36,158.16	IDR 56,949.09
	Wall Paint	1575	m²	IDR 55,269.50	IDR 87,049.46
D	4th Floor (Elev. +13,500)				
	Lightweight Brick Wall 600 x 200 100 mm	832.5	m²	IDR 154,303.99	IDR 128,458,068.43
	Plaster	1665	m²	IDR 59,927.89	IDR 99,779.93
	Plastering	1665	m²	IDR 36,158.16	IDR 60,203.32
	Wall Paint	1665	m²	IDR 55,269.50	IDR 92,023.717.50
E	5th Floor (Elev. +18,000)				
	Lightweight Brick Wall 600 x 200 100 mm	643.5	m²	IDR 154,303.99	IDR 99,294,615.06
	Plaster	1287	m²	IDR 59,927.89	IDR 77,127.194
	Plastering	1287	m²	IDR 36,158.16	IDR 46,535.54
	Wall Paint	1287	m²	IDR 55,269.50	IDR 71,131.846
F	6th Floor (Elev. +22,500)				
	Lightweight Brick Wall 600 x 200 100 mm	706.5	m²	IDR 154,303.99	IDR 109,015,766.18
	Plaster	1413	m²	IDR 59,927.89	IDR 84,678.10857
	Plastering	1413	m²	IDR 36,158.16	IDR 51,091.47

No	Work Description	Volume	Unit	Unit Price	Total Price
	Wall Paint	1413	m²	IDR 55,269.50	IDR 78,095,803.50
G	7th Floor (Elev. +27,000)		m²		
	Lightweight Brick Wall 600 x 200 100 mm	864	m²	IDR 154,303.99	IDR 133,318,643.99
	Plaster	1728	m²	IDR 59,927.89	IDR 103,555.39
	Plastering	1728	m²	IDR 36,158.16	IDR 62,481.29
	Wall Paint	1728	m²	IDR 55,269.50	IDR 95,505,696.00
		Total Lightweight Brick Wall Work			**IDR 2,667,369,000.00**

Based on **Table 2** and **Table 3**, a comparison of the cost analysis results shows a significant difference between the use of EPS sandwich panels and lightweight brick walls. The total cost of the sandwich panel wall project is higher than that of the lightweight brick wall. This is due to the relatively high unit price of EPS sandwich panel materials. In addition, the use of EPS sandwich panels can reduce indirect costs-that is, costs not directly related to construction work. These costs include supervision, project management, and other general expenses beyond direct construction costs (Desembardi et al., 2024). Therefore, although material costs are higher, the overall project cost can be more economical, particularly in high-rise building projects. A cost analysis was conducted to compare the total cost requirements for using lightweight brick walls and EPS sandwich panels. The calculations were based on the work components involved for each material. The results of this comparison are presented in **Figure 2** to facilitate visualization of the cost differences.

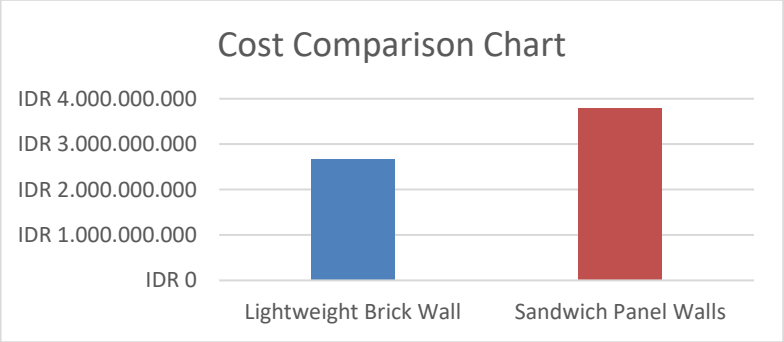

Figure 2. Cost Comparison Chart

Based on **Figure 2,** a difference in cost analysis results is evident between lightweight brick walls and sandwich panel walls, with a cost difference of IDR1,129,856,000.00**.**

3.3 Work Time

Productivity calculations for each task were performed first before proceeding to the construction duration calculations. The labor requirements for both EPS sandwich panel walls and lightweight brick walls are the same, at 30 workers. The productivity are shown in **Table 4** and **Table 5.**

Table 4. Productivity of EPS Sandwich Panel and Lightweight Brick Wall Work

No	Work	Productivity	Description
1	EPS Sandwich Panel	14.28 m²	days/worker
2	Lightweight Brick Laying	5.80 m²	days/worker
3	Plaster	13.47 m²	days/worker
4	Plastering	15.00 m²	days/worker
5	Painting	25.00 m²	days/worker

Table 5. Total Work for EPS Sandwich Panel and Lightweight Brick Walls

No	Work	Volume	Total Work Duration (days)
1	EPS Sandwich Panel	5,836.5	13.62 = 14
2	Lightweight Brick	5836.5	33.54 = 34
3	Plaster	11,673	28.89 = 29
4	Plastering	11673	25.94 = 26
5	Painting	11673	15.56 = 16

To determine the duration of the work, it is important to consider the area of work completed divided by productivity and the number of workers. **Table 4** shows the productivity calculations for each task, and **Table 5** shows the total duration for each task. The results indicate that the duration of work on EPS sandwich panel walls is shorter than that of lightweight brick walls. The installation methods of both materials significantly affect project duration. Lightweight brick walls require multiple stages, such as installation, plastering, finishing, and painting. In contrast, the use of EPS sandwich panel wall materials allows for faster installation due to their prefabricated and modular nature. The time estimates were calculated based on the work phases and the volume of each material. The results of this comparison are shown in **Figure 3** to provide a visual representation of the difference in completion times.

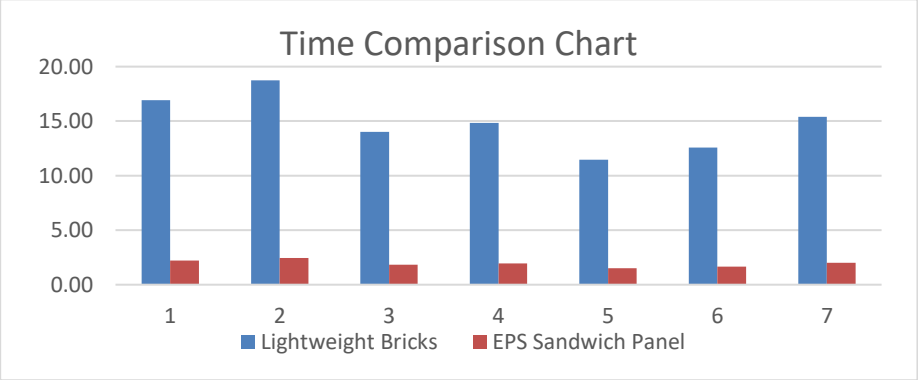

Figure 3. Time Comparison Chart

In **Figure 3**, the total difference in project duration between EPS sandwich panel walls and lightweight brick walls is 91 working days. The following table summarizes the three aspects of the comparative analysis between EPS sandwich panel walls and lightweight brick walls, as shown in **Table 6.**

Table 6. Comparison of EPS Sandwich Panel Walls and Lightweight Brick Walls

Aspect	EPS Sandwich Panel Walls	Lightweight Brick Walls	Difference
Quality	Lightweight, consistent surface, moisture-resistant, adequate compressive strength, self-extinguishing properties, and good thermal insulation	Heavier weight, susceptible to moisture (depending on the quality of the finish), higher compressive strength, better fire resistance, and offers high flexibility in architectural design applications	-
Cost	Higher cost of IDR 3,797,225,000.00	Lower cost of IDR 2,667,369,000.00	42.37%
Time	Faster installation (14 days)	Relatively long installation time (105 days)	86.67

In **Table 6**. the comparison results show differences in quality, cost, and time between the two materials. EPS sandwich panels have different quality characteristics compared to lightweight bricks. In terms of cost, EPS sandwich panels are more expensive than lightweight bricks. Meanwhile, in terms of installation time, EPS sandwich panels require a shorter duration.

4. CONCLUSION

Based on the research findings and analysis, EPS sandwich panel walls demonstrate advantages in installation speed and functional quality, particularly regarding moisture resistance and thermal insulation capabilities. Conversely, lightweight brick walls offer advantages in terms of cost, fire resistance, higher compressive strength, and design flexibility to meet architectural needs; however, they require additional work stages that extend the construction duration. The cost difference between EPS sandwich panel walls and lightweight brick walls is IDR 1,129,856,000.00. Meanwhile, the total difference in construction time amounts to 91 working days. This indicates that reducing the construction duration through the use of EPS sandwich panel walls can lower project overhead costs, meaning that total costs are influenced not only by material prices but also by the length of the construction period. Therefore, time efficiency can enhance the overall effectiveness of project management. Considering the interrelationship between quality, cost, and time, the use of EPS sandwich panels is deemed to meet the requirements as a suitable alternative wall material for the interior of an eight-story lecture building.

REFERENCES

Ajar, I. P., & Dofir, A. (2021). Analisis perbandingan biaya dan waktu pada pekerjaan dinding drywall (Partisi Rockwool) dan batako press. *Jurnal Artesis*, *1*(1), 96–103.

Busher, S., & Varatharajapuram Govindarajulu, K. (2023). Thermal performance and reduced carbon footprint of precast concrete sandwich wall panels (PCSWPs) with composite shear connector–an experimental assessment. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *45*(4), 12201–12214.

Desembardi, F., Nur Fajar, M., Widodo, S., & Lintang Tiara Yon Saputri, D. (2024). Perbandingan metode percepatan pekerjaan terhadap biaya langsung dan biaya tidak langsung. *Konstruksia*, *16*(1), 58–66.

Dhaif, M., & Stephan, A. (2021). A life cycle cost analysis of structural insulated panels for residential buildings in a hot and arid climate. *Buildings*, *11*(6), 1–23.

Dinas PU Bina Marga dan Cipta Karya Provinsi Jawa Tengah. (2023). *Harga satuan pekerjaan konstruksi dan harga satuan dasar bahan bangunan*. PUPR.

Effendi, M. C., & Pandulu, G. D. (2020). Analisis penggunaan metode half slab terhadap waktu pelaksanaan pembangunan proyek apartemen caspian tower surabaya. *Prosiding Seminar Nasional Teknologi Industri, Lingkungan Dan Infrastruktur*, *3*, D1.1-D1.7.

Fauzie, M., & Wibowo, D. E. (2024). Pengembangan e-book dalam mata kuliah manajemen konstruksi pada program studi Teknik Sipil S1 Departemen Pendidikan Teknik Sipil dan Perencanaan Universitas Negeri Yogyakarta. *Jurnal Pendidikan Teknik Bangunan*, *4*(2), 135–146.

Hapsari, K., Rahmi, A. T., & Deni, D. P. (2023). Efektivitas dinding sandwich panel dan precast ACC panel terhadap biaya dan waktu. *Jurnal Manajemen Teknologi & Teknik Sipil*, *6*(2), 123–137.

Hidayat, F. (2018). Analisis perbandingan biaya, waktu, material, dan tata laksana pekerjaan dinding menggunakan bata ringan, sandwich panel dan beton precast pada proyek pembangunan rumah sakit "Stc" di Kota Jakarta. *Jurnal Teknik Sipil*, *7*(2), 40–51.

Husain, B. A., Mangare, J. B., & Pratasis, P. A. K. (2022). Produktivitas pasangan dan plesteran dinding bata ringan pada kasus pembangunan mess dan prasarana DENMADAM XIII/MDK. *Tekno*, *20*(81), 203–207.

Iwan Christianto. (2024). Analisis perbandingan waktu dan biaya kelayakan penggunaan material bata ringan dan sandwich PU panel. *Jurnal Penelitian Rumpun Ilmu Teknik*, *3*(4), 27–36.

Kumar, P., Nighot, N. S., Kumar, R., Sharma, S., Kirgiz, M., & Goyal, A. (2024). Advancements in precast concrete sandwich panels for load bearing structures. *Applied Engineering and Technology*, *3*(1), 58–69.

Lakshmikandhan, K. N., Harshavardhan, B. S., Prabakar, J., & Saibabu, S. (2017). Investigation on wall panel sandwiched with lightweight concrete. *IOP Conference Series: Materials Science and Engineering*, *225*(1).

Maryani, D., Saputra, A., & Triwiyono, A. (2019). Kuat tekan panel dinding beton ringan expanded polystyrene dengan lapis luar papan kalsium silikat. *Teknisia*, *XXIV*(1), 1–10.

Maulana, B. F., Abadiyah, S., & Safitri, R. A. (2024). Analisa perbandingan bekisting semi sistem (knockdown) dengan bekisting konvensional berdasarkan RAB. *Jurnal PendidikanTeknik*

Bangunan, *4*(2), 147–156.

Mohamed, N. A., El-Dash, K. M., Attia, T. M., & Abdel-Monem, M. (2023). Analysis of alternative building Envelope Solutions to Improve Energy Efficiency. *2023 2nd International Conference on Smart Cities 4.0, Smart Cities 4.0 2023*, 138–145.

One, L., Sunarno, Y., Manga', J., Palungan, M. B., Hijriah, Buarlele, L., Tangaran, B., Muhsar, M., & Aswad, N. H. (2025). Mekanika Bahan. *HEI Publishing Indonesia.*

Pratiwi, S., Saputra, A., & Awaludin, A. (2020). Kuat tekan sandwich panel expanded polysterene penambahan plesteran dan kawat loket. *Teknisia*, *XXV*(2), 69–77.

Setyawan, A., & Pakpahan, F. (2024). Analisis biaya dan waktu pembangunan gedung FPEB UPI menggunakan sistem modular pada dinding. *Matriks Teknik Sipil 12*(2), 1–11.

Silva, A. R. da, Filberg, D. F., Alves, F. G. T., & Araújo, I. M. (2024). Comparativo de custo entre os sistemas insulated concrete forms e alvenaria de blocos cerâmicos. *Brazilian Journal of Animal and Environmental Research*, *7*(1), 801–808.

Thangarasu, A., & Henderson, J. H. (2022). Thermal and structural behaviour of sandwiched reinforced cement concrete wall panels. *Materials Science-Medziagotyra*, *28*(4), 506–518.