The 14th International Symposium of the Malay Archipelago

ORGANIZED BY :

Universiti Teknologi MARA Perak Branch

CENTRE FOR KNOWLEDGE & UNDERSTANDING OF TROPICAL ARCHITECTURE & INTERIOR KUTAI

HOSTED BY :

Universitas Negeri Makassar UNM

BLU eSPEED

'Anging Mammiri Nusantara'
Sulawesi Selatan

e-ISSN : 3030-5543

PROCEEDINGS INTERNATIONAL SYMPOSIUM NUSANTARA SIMPORA XIV

'SIMPOSIUM NUSANATARA KE-14' | October 2023

STRATEGIC PARTNER :

USK Universitas Syiah Kuala

PROCEEDINGS INTERNATIONAL SYMPOSIUM NUSANTARA XIV

SIMPORA XIV: 2023

Organised by:

Centre for Knowledge and Understanding of Tropical Architectural and Interior (KUTAI)
Universiti Teknologi MARA Perak Branch
Seri Iskandar Campus, Perak, MALAYSIA

Diterbitkan oleh:

Unit Penerbitan UiTM Perak

Alamat:
Unit Penerbitan UiTM Perak,
Pejabat Jaringan Industri, Masyarakat dan Alumni (PJIMA)
Universiti Teknologi MARA, Perak Branch,
32610 Seri Iskandar Perak, Malaysia.

05-3742716

uitmperakpress@gmail.com

Perpustakaan Negara Malaysia Cataloguing in Publication Data

No e- ISSN: 3030-5543

Cover Design: Ismail Hafiz Salleh
Typesetting : Nur Huzeima Mohd Hussain

PROCEEDINGS SIMPORA XIV 2023: EDITORIAL BOARD

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Centre for Knowledge and Understanding of Tropical Architectural and Interior (KUTAI)

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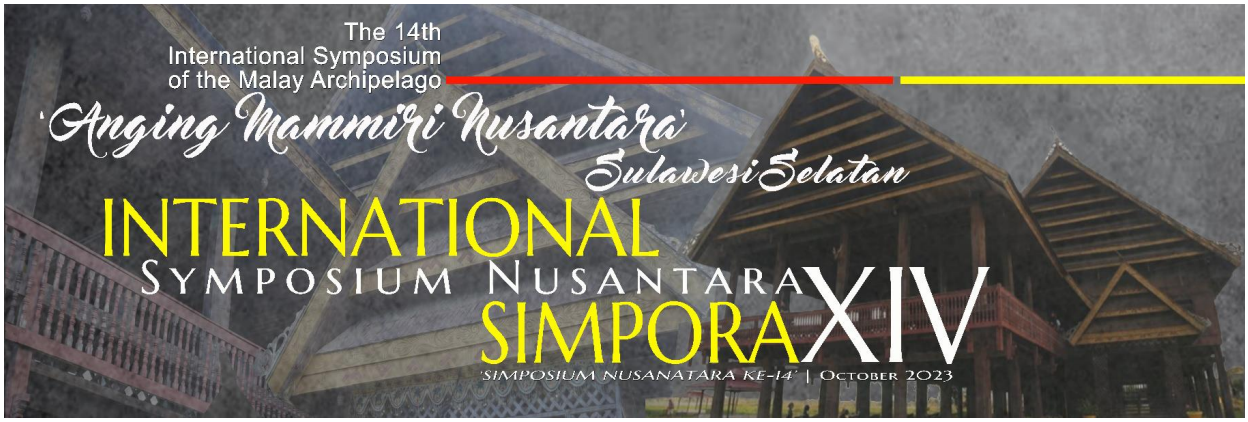

UTILIZATION OF PLASTERED-BAMBOO FOR POST-DISASTER RESIDENTIAL WALL CONSTRUCTION: A STUDY ON COST EFFICIENCY COMPARED TO MASONRY WALL

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Abstract: Plastered-bamboo wall construction has long been known and has been built as a post-disaster shelter in several locations in Indonesia and is starting to be introduced to people in big cities as an alternative to brick walls. This study aims to assess the cost efficiency of plastered-bamboo walls compared to brick walls. The object of the study was a residential house measuring 5 m x 6 m located in Makassar city. The analysis of the unit cost of work refers to the SNI and observations during the construction process. The result shows that the cost savings obtained using plastered-bamboo walls is 11%. The ratio between labor and material costs is 65%:35% while the ratio of labor and material costs for brick wall construction is 44%:56%. Cost savings are obtained from the low cost of materials; however, the construction wage cost of plastered-bamboo walls is 20% higher than brick walls. The highest labor costs are in plastering and painting work, which are caused by the longer process of plastering columns and beams which require accuracy and neatness in the process. This research recommends a prefabricated plaster brick wall construction system to overcome the high labor costs.

Keywords**:** Plastered-bamboo, bamboo wall construction, post-disaster housing, cost efficiency, sustainability

INTRODUCTION

Bamboo is known as a grass-type plant and is one of the fastest growing crops. It can be found in almost all regions in Indonesia. Based on the data from the Central Bureau of Statistics (2022), the production of bamboo plants in Indonesia in 2022 reached 66,921,536 stems, a vast amount to be a source for various products to increase people's income and welfare. However, despite its abundance and potential, bamboo has not received optimal attention in its development and utilization for building construction in Indonesia. For example, the utilization of bamboo in Barru Regency, South Sulawesi, and Bogor City, West Java, ranged in a simple form such as for fences, temporary buildings, chicken cages, and other uses that still have low added value (Jannah & Taskirawati, 2019; Muttaqin et al., 2023). Bamboo has a tensile strength which is almost equivalent to steel (Durga G et al., 2019; Harison et al., 2017; Rahim et al., 2020). As a biomass material, bamboo falls into the category of renewable materials that can be a solution to the issue of environmental damage caused by the massive use of unsustainable materials such as bricks (Baghel & Thakkar, 2017). If preserved properly, bamboo can be durable for up to 20 years (Putri & Dewi, 2020). The nature of bamboo makes bamboo building construction more resistant to earthquakes and wind (Auman et al., 2018; Mite-Anastacio et al., 2022).

The use of bamboo for permanent building wall construction has been recognized in Indonesia for a long time. Plastered-bamboo wall construction was once used by the Dutch, and after decades, some of these plastered-bamboo residential buildings still survive and are in good condition (Widyowijatnoko & Mustakim, 2015). Wall construction made of bamboo slats woven and then plastered is also known as *Rumah Bambu Plester* or *Mabuter* (Tanuwidjaja, 2011). This provides evidence that bamboo plaster wall construction can provide good performance, as an alternative wall construction that still utilizes the potential of bamboo. Nonetheless, plastered-bamboo wall construction is still far less common than the use of brick walls (Susenas, 2021). The plastered-bamboo wall construction technology can be built in stages and can be done by the local community with a skill level equivalent to that of a semi-skilled artisan. Because of its ease of construction, plastered-bamboo houses are very suitable to be built in remote areas affected by disasters to meet post-disaster housing needs. Currently, plastered-bamboo houses have been built in several post-disaster locations in Indonesia, such as in Aceh, Yogyakarta and Central Java, Lombok Island, and Palu (Widyowijatnoko & Mustakim, 2015). In line with its advantages, plastered bamboo can also be introduced to people in urban areas as an alternative to red brick. Plastered-bamboo houses have been built in several major cities in Indonesia, including Medan, Bandung, and Makassar. However, to further increase public interest in switching from brick to bamboo, a comprehensive study on the performance of plastered-bamboo walls is also needed. From previous studies, it is known that plastered bamboo walls have good performance as required for residential wall components. Based on the results of fire resistance testing, it is known that plastered bamboo walls have a fire resistance level of two hours (Tambunan et al., 2022).

The use of bamboo as a substitute for red brick can also reduce the cost of procuring construction materials. However, research is still needed on how efficient the use of plastered bamboo is considering that cost is one of the main factors that determine the level of public acceptance of this type of construction. From previous research, it is known that replacing red bricks can save construction costs by 31.17% (Meldawati et al., 2019). Nevertheless, the study did not include wage costs, even though the wage cost component is an important factor considering that plastered-bamboo construction is new. Construction workers who are not familiar with plastered-bamboo construction may be more skilled and quicker at building with red bricks than constructing plastered-bamboo walls. This study will examine the cost efficiency of plastered-bamboo wall construction for residential buildings compared to red brick

walls and the relationship between construction design and cost. The results of the study will be utilized to refine plastered-bamboo construction to meet the requirements of sustainable and affordable construction.

METHODS

The research was conducted during the construction of a simple 5 meters x 6 meters residential building built to a scale of 1:1 located in Makassar city (Figure 1). The walls of the building are made entirely of woven bamboo plastered with mortar (Figure 2). The construction of the plastered-bamboo wall was carried out in several stages by four construction workers as shown in Figure 3 below.

Figure 1 Building plan and modules of plastered-bamboo wall panels.
Image Copyright, Authors (2023)

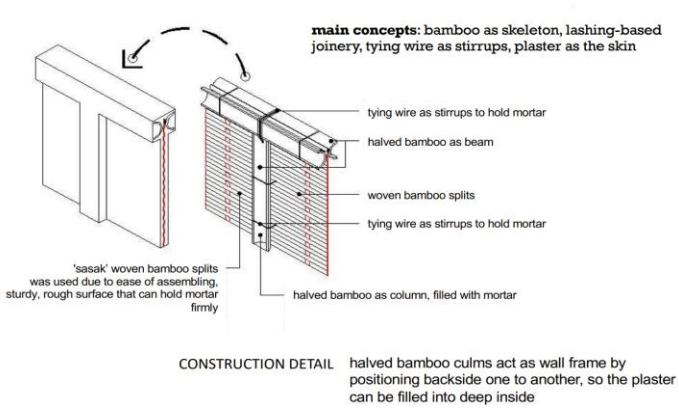

Figure 2 Plastered-bamboo wall construction details.
Image Copyright, Widyowijatnoko (2023)

1. Panels making

2. Woven bamboo panel (top), transportation of materials to the project site (bottom)

3. Installation of columns and ring beams

4. Making holes for windows

5. Installation of column anchors

6. Installation of panels

7. Termite repellent and chicken wire installation

8. Wall and column plastering

Figure 3 Plastered-bamboo construction stages.
Image Copyright, Authors (2023)

In this study, unit price analysis was conducted for plastered bamboo wall construction only (excluding foundation, roof, and window/door costs), as well as for red brick walls. The materials necessary for constructing bamboo walls include woven bamboo, chicken wire, termite-proofing, and concrete wire. The analyzed bamboo wall area is calculated based on the total area of all bamboo panel modules minus the area of door, window, column, and beam openings (Table 1).

Table 1 Wall area calculation

Component	**Area (m^2)**
Wall panels	59.73
Columns	8.91
Beams	3.30
Opening area (doors and windows)	16.60
Remaining wall area	**34.22**
Total 2-sided wall area	**68.44**

The calculation of plastered-bamboo wall construction cost is divided into the work of making and installing bamboo panels and columns, plastering work, and compounding work. For the fabrication and installation of bamboo, index values were derived from observations made during the construction process. The unit price analysis for plastering and compounding work for both bamboo walls and red brick walls are referred to as SNI 6897:2008 and SNI 2837:2008. The prices of materials and wages used in this study reflect the prevailing rates in Makassar during July-August 2023.

RESULT AND DISCUSSION

Based on observation during construction work, the cost index value of making and installing woven bamboo until it is ready to be plastered is listed in Table 2. The work of making bamboo

panels and installing bamboo panels is done by different craftsmen. The cost of manufacturing woven bamboo per m^2 includes the cost of materials and wages, while the cost of installing woven bamboo panels includes the costs of application of chicken wire, termite proof, and concrete wire. Transportation costs are not included in the analysis assuming the woven bamboo is made at the project site. DW stands for 'daily workers', a term for workers paid per day.

Table 2 Cost of woven bamboo wall

Construction Needs		**Unit**	**Index**	**Price (IDR)**	**Cost (IDR)**
Materials	Woven bamboo	m^2	1	65,000	65,000
	Chicken wire	m^2	2	12,500	25,000
	Termite proof	kg	0.1	22,000	2,200
	Concrete wire	kg	2	1,160	2,320
Labor	Worker	DW	0.002	100,000	208
	Bricklayer	DW	0.01	150,000	1,563
	Head mason	DW	0.006	150,000	938
	Foreman	DW	0.001	150,000	188
Panel Making and Installation Cost per m^2					**97,416**
Total Cost of Bamboo Walls		34.22	m^2		**3,333,570**

Calculation of plastering and compounding work costs is separated between the entire woven wall and columns and beams (see Table 3 and Table 4). This is because there are right angles in the columns and beams that require higher accuracy compared to the plastering work of the wall, hence the index value of workers is equivalent to wall profiling work. In this study, the index value of plastering and compounding of woven bamboo is the same as the index value of masonry walls.

The cost calculation of column and beam construction work is separate from the cost calculation of bamboo wall panels because they require different volumes of materials and different construction methods. Column and beam construction involves using whole bamboo culms split in half, along with concrete wire and chicken wire. The results of the unit cost analysis of column and beam construction work are shown in Table 5.

Table 3 Unit price analysis of plastering work (1 PC : 5 sand), 15 mm thick

Construction Needs		**Unit**	**Index**	**Price (IDR)**	**Cost (IDR)**
Materials	Portland cement (PC)	kg	5.184	1,450	7,517
	Sand	m^3	0.026	300,000	7,800
Labor	Worker	DW	0.3	100,000	30,000
	Bricklayer	DW	0.15	150,000	22,500
	Head mason	DW	0.015	150,000	2,250
	Foreman	DW	0.015	150,000	2,250

Wall Plastering Cost (2 sides) per m^2			**72,317**
Total Cost of Wall Plastering	68.44	m^2	**4,949,362**

Table 4 Unit price analysis of wall compounding work

Construction Needs		**Unit**	**Index**	**Price (IDR)**	**Cost (IDR)**
Materials	Portland cement (PC)	kg	3.25	1,450	4,713
Labor	Worker	DW	0.2	100,000	20,000
	Bricklayer	DW	0.1	150,000	15,000
	Head mason	DW	0.01	150,000	1,500
	Foreman	DW	0.01	150,000	1,500
Wall Compounding Cost (2 sides) per m^2					**42,713**
Total Cost of Wall Compounding		68.44	m^2		**2,923,244**

Table 5 Unit price analysis of column and beam construction

Construction Needs		**Unit**	**Index**	**Price (IDR)**	**Cost (IDR)**
Materials	Bamboo	culm	0.50	25,000	12,500
	Termite proof	kg	0.03	22,000	660
	Concrete wire	kg	0.30	22,000	5,500
Labor	Worker	DW	0.04	100,000	4,167
	Bricklayer	DW	0.03	150,000	4,688
	Head mason	DW	0.01	150,000	1,563
	Foreman	DW	0.01	150,000	1,563
Columns and Beams Construction per m^2					**30,639**
Total Cost of Columns and Beams Construction		49.00	m^2		**1,501,319**

Based on field observations, the work of plastering and caulking the columns and beams that serve as the stiffening frame of the bamboo wall takes longer than the work of plastering and compounding the walls. Therefore, the index value of this work is greater than the index value of plastering and wall compounding work. The results of the unit price analysis for the plastering and compounding of columns and beams are listed in Table 6 and Table 7.

Table 6 Unit price analysis of columns and beams plastering

Construction Needs		**Unit**	**Index**	**Price (IDR)**	**Cost (IDR)**
Materials	Portland cement (PC)	kg	5.18	1,450	7,157
	Sand	m^3	0.03	300,000	7,800
Labor	Worker	DW	0.09	100,000	9,000
	Bricklayer	DW	0.50	150,000	75,000
	Head mason	DW	0.04	150,000	6,000
	Foreman	DW	0.004	150,000	600

Columns and Beams Plastering per m^2			**105,917**
Total Cost of Columns and Beams Plastering	30.88	m^2	**3,270,711**

Table 7 Unit price analysis of column and beams compounding

Construction Needs		**Unit**	**Index**	**Price (IDR)**	**Cost (IDR)**
Materials	Portland cement (PC)	kg	3.25	1,450	4,713
Labor	Worker	DW	0.18	100,000	18,000
	Bricklayer	DW	0.25	150,000	37,500
	Head mason	DW	0.01	150,000	1,500
	Foreman	DW	0.01	150,000	1,500
Columns Compounding Cost per m^2					**63,213**
Total Cost of Columns Compounding		31.37	m^2		**1,983,103**

Based on the results of the unit price analysis that has been carried out, it is known that the total cost of plastered-bamboo walls for a type 30 house measuring 5 meters x 6 meters with a plastered bamboo wall area of 34.22 m^2 is IDR 31,706,190, - or an average of IDR 926,540,-/m^2. In terms of cost composition, the largest cost component is labor wages (65%) while materials only account for 35% of the total wall cost (Figure 4, left).

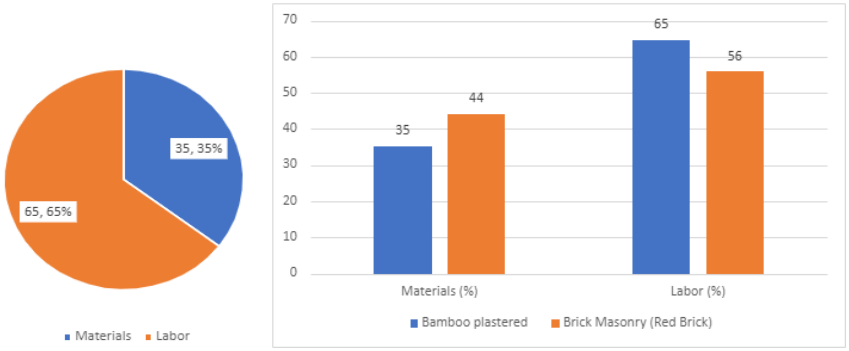

Figure 4: (left) Material vs labor cost percentages of plastered-bamboo wall, (right) Materials vs labor cost percentage of plastered-bamboo wall and masonry wall.

The construction cost of a plastered bamboo wall was compared to the construction cost of a brick wall with the same size of wall surface area. The brick wall construction cost is calculated based on the following brick wall specifications: brick size 5x11x22 cm, thickness ½ brick, mortar mix 1 PC : 5 Sand, reinforced concrete column cross-section 11 cm x 11 cm, height 2.8 m, number of columns 12 pieces. The calculation of construction costs is based on SNI 6897:2008 and SNI 2837:2008, then compared with the cost of plastered-bamboo walls. The results are as follows (Figure 5).

Figure 5: (left) Cost comparison of plastered-bamboo wall and brick masonry wall, (right) materials vs labor cost percentage of plastered-bamboo wall and masonry wall

The comparison results in Figure 5 show that the cost per m^2 of plastered bamboo walls is lower than that of brick walls. However, the difference is relatively small. In fact, in terms of construction type, plastered bamboo is simpler than masonry walls. In the construction of plastered-bamboo walls, there is no casting of reinforced concrete columns and beams, which will greatly save the time and labor required. Similarly, the work of making and installing wall panels does not take as long as the work of preparing masonry. However, when looking at the percentage cost comparison between the two types of construction (Figure 4), the percentage cost of plastered-bamboo wall construction is much higher than that of brick wall construction. Based on the author's experience, there are several factors that cause longer construction time including complicated construction, unskilled workers, lack of supervision, and workers not mastering the appropriate construction stages. Based on the results of the cost comparison between the components of the plastered-bamboo wall, it was found that the cost of plastering and drawing was higher than the cost of the same work on the brick wall (Figure 5). When related to the design of the wall, which has many columns, it can be concluded that the area plastered and compounded on the bamboo wall is larger than that of the brick wall. The second factor is the complexity of the column plastering and compounding work on the plastered-bamboo wall, which is caused by the large number of corners and thus requires more time.

Overall, the study found that the construction cost of plastered-bamboo walls was slightly lower than the construction cost of bricks. However, the level of efficiency expected by replacing red bricks with plastered bamboo is not significant. To be able to compete with the brick wall construction that has long been recognized by the public, one way is to make prefabricated systems and modular walls. Simultaneously, workers must undergo training and acquire the necessary skills to master plastered-bamboo wall construction until they achieve proficiency comparable to that required for brick wall construction.

CONCLUSIONS

This study aimed to determine the cost efficiency of plastered-bamboo wall construction compared to brick wall and the factors affecting it. This research shows that the construction cost of plastered-bamboo walls per m^2 is lower than the construction cost of red brick walls. However, the wage cost of plastered-bamboo wall work is much higher than the material cost. The work of plastering and accurately calculating the columns in plastered bamboo walls, which demands precision, increases the duration of work, and consequently leads to higher total wage costs. To improve the efficiency of plastered-bamboo wall construction and to compete with brick walls, prefabricated systems and modular walls are recommended.

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