IJMECIE International Journal of Mechanical, Electrical and Civil Engineering

E-ISSN: 3047-4531
P-ISSN: 3047-4523

Research Article

Evaluation of the Selection and Application of Environmentally Friendly Materials in Row Housing Design: A Case Study of Cemara Asri, Medan

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Abstract: The use of building materials plays a crucial role in determining the quality of the built environment, particularly in the context of row housing in densely populated urban areas. This study aims to evaluate the types of materials used in the construction of row housing in Cemara Asri, Medan, with a focus on sustainability and environmental friendliness criteria. The methods employed include direct site surveys and literature studies related to the characteristics of both interior and exterior materials applied to housing units. The research findings indicate that most of the materials used—such as red bricks, ceramic tiles, clay roof tiles, and concrete ventilation blocks—possess good energy efficiency and durability potential. However, they do not fully meet sustainability standards in terms of production processes and waste management. The study also found that residents' awareness of environmentally friendly material selection remains limited, and the procurement of materials tends to follow local availability and economic considerations. These findings are expected to serve as a foundation for improving environmentally friendly material planning in row housing developments in other urban areas.

Keywords: Building Materials; Environmentally Friendly; Material Selection; Medan; Row Housing.

Received: October 19, 2025
Revised: December 24, 2025
Accepted: February 28, 2026
Published: April 30, 2026
Curr. Ver.: April 30, 2026

1. Introduction

The rapid growth of housing development in urban areas such as Medan demands more sustainable design approaches, particularly in the selection of building materials. Row housing, as a form of mass housing, offers land-use efficiency but often presents significant challenges related to thermal comfort and aesthetics. For instance, a study conducted in Surakarta highlighted that the shape and orientation of housing units play a vital role in optimizing indoor comfort and reducing cooling energy use—factors strongly influenced by the materials used for roofs and walls (Ilmi & Sunarya, 2024).

Environmentally friendly materials must not only meet technical requirements such as strength and weather resistance but also have a low carbon footprint throughout their production, use, and end-of-life phases. Recent developments in Life-Cycle Assessment (LCA) approaches have shown that materials such as lightweight concrete and bio-based building materials (e.g., bamboo, straw) can significantly reduce emissions over the building's lifespan (Estokova & Samesova, 2021; Wikipedia, 2025). Similarly, a study in the United Arab Emirates demonstrated that building orientation and material choice can reduce indoor temperatures by up to 0.5°Can important consideration for addressing the urban heat island effect (Muhdy et al., 2025).

In this context, the present study focuses on evaluating the types and characteristics of materials used in the row housing area of Cemara Asri, Medan. The research is centered on how these materials meet sustainability criteria including energy efficiency, tropical climate resilience, local availability, and environmental impact. Furthermore, the study identifies influencing factors in the material selection process, such as cost, residents' aesthetic preferences, and awareness of green building principles. It is expected that the findings from this evaluation will serve as a reference for improving design practices and material procurement policies for more sustainable row housing in other urban areas. Several previous studies have examined the use of sustainable building materials in tropical residential contexts. For example, research by Satola et al. (2020) investigated greenhouse gas (GHG) emissions across the life cycle of residential housing in tropical/subtropical climates and found that using lightweight materials such as lightweight concrete and bio-based plywood significantly reduces embodied emissions.

This is particularly relevant as a comparison to Cemara Asri, which still predominantly uses red bricks and concrete ventilation blocks. Additionally, a study in Thailand by Viriyaroj et al. (2024) conducted LCA on five standard housing designs and concluded that improving the building envelope materials and substituting cementitious materials are key for mitigating GHG emissions. These findings support the need to evaluate alternative material options in Cemara Asri, such as clay tiles and cork wood, which have the potential to be more environmentally friendly. Dipasquale et al. (2025), in their study “Sustainable Design of a Tiny House,” compared the ecological performance of earth-based building systems with traditional industrial materials and found that locally sourced natural materials provide significant environmental advantages. Although conducted on a small-scale dwelling, their LCA-based evaluation method can be adopted as a framework for assessing materials in Cemara Asri’s row housing. In the Southeast Asian context, research in Indonesia by Fitriani & Ajayi (2023) found that awareness and incentives for implementing environmentally friendly practices remain limited, particularly in sustainable material procurement. This supports the initial observation that material selection in Cemara Asri is more strongly driven by local availability and cost than by environmental considerations.

Compared to these previous studies, this research presents several points of novelty: It focuses specifically on row housing in the city of Medan a housing typology that remains under-researched in Southeast Asia, despite its complexity in terms of tropical climate and linear layout, it combines both quantitative and qualitative evaluations of interior and exterior materials, employing not only LCA but also practical observation and interviews, and it analyzes material selection factors from aesthetic, economic, cultural, and local green building awareness perspectives, rather than solely from technical or GHG emission aspects. Thus, while energy consumption and environmental impacts of materials have been widely studied in various contexts, this study provides new insights into how tropical row housing interacts with sustainability criteria and local culture, and how material selection practices can inform environmentally conscious housing design within the context of Indonesia’s urbanization. Based on the above discussion, the research questions for this study are as follows, What types of materials are used in the row housing area of Cemara Asri?, Do these materials meet environmentally friendly criteria?, What factors influence the material selection and procurement process in the row housing of Cemara Asri?.

2. Theoretical Framework

The theories supporting this research encompass several topics, namely: (a) sustainable material selection; (b) Life Cycle Assessment (LCA); (c) characteristics of tropical row housing; and (d) bio-based materials. The explanation of each topic is as follows:

Material Selection and Sustainability

The concept of green building emphasizes that building materials should be selected based on environmental criteria throughout their life cycle—including production, usage, and end-of-life phases (demolition) (Mulya et al., 2020; Nuraini, 2024; Rani et al., 2025; ISO, 2006). Akbar et al. (2023) state that the implementation of sustainable materials can significantly enhance energy savings and water management, as well as reduce carbon emissions.

Life Cycle Assessment (LCA)

The LCA method is a comprehensive approach used to evaluate the environmental impacts of materials, covering embodied energy and greenhouse gas (GHG) emissions from cradle to grave (Gao et al., 2022; LCA, 2023). Satola et al. (2021) and Theerakulpisut et al. (2024) demonstrated that lightweight and bio-based materials (e.g., lightweight concrete, wood) can substantially reduce embodied carbon in tropical housing projects.

Characteristics of Tropical Row Housing

The design of row housing in tropical climates presents unique challenges related to thermal comfort, ventilation, and lighting. Garde et al. (2012) and Boyer et al. (2012) emphasize two main strategies: optimizing building orientation and applying passive components such as natural ventilation and shading to enhance indoor comfort (Garde et al., 2012; Nuraini et al., 2022). This is relevant to the assessment of Cemara Asri, which features a block layout with uniform orientation.

Bio-Based Materials

Bio-based materials such as bamboo, straw bales, and certified wood are considered to have low embodied carbon due to their renewable nature and good thermal insulation properties (Latapie et al., 2023). Research by Morel et al. (2021) also indicates that the use of local natural materials supports the circular economy in construction. An evaluation of environmentally friendly materials in tropical row housing, addressing a research gap where prior studies have largely focused on single or small-scale dwellings. The integration of LCA with a mixed-methods approach both quantitative and qualitative on interior and exterior materials.An analysis of material selection factors, including aesthetics, local culture, and resident awareness beyond the dominant considerations of cost and availability.

3. Research Methodology

Research Approach and Type

This study employs a descriptive-qualitative approach, supported by limited quantitative data in the form of measurements and categorization of building materials. This type of research was chosen to systematically and comprehensively describe the characteristics of material usage in row housing and to evaluate its alignment with sustainable building material principles.

In addition, a single case study approach was applied, focusing on the Cemara Asri residential complex in Medan, North Sumatra. This area was selected as it represents a real-world example of row housing with high occupancy density, architectural variety, and relevance as a model for urban tropical housing.

Research Location and Object

The research was conducted in Cemara Asri Housing Complex, located in Percut Sei Tuan Subdistrict, Deli Serdang Regency (bordering Medan City). The research objects were inhabited and/or renovated row housing units, including both interior and exterior building components. Initially, six houses from different blocks (with varied functions and renovation levels) were purposively selected. However, only three samples were available and agreed to be visited and provided relevant data for this research. The research location is illustrated in Figure 1.

Figure 1. Research Location.
(Source: Adapted by Author based on Google Maps, 2025).

Data Collection Techniques

Data were collected using three main techniques: field observation, semi-structured interviews, and literature review with technical documentation. Field observation included direct observation of building elements such as wall materials, flooring, roofing, ventilation, and window frames, as well as visual documentation through photographs and element sketches. The observation also involved identifying material types and construction systems, along with recording installation locations, material conditions, and material lifespan. Semi-structured interviews were conducted with house residents, local construction foremen, and building material suppliers. The interview topics covered reasons for material selection, material sources, aesthetic and functional considerations, and residents' awareness of green materials. The data obtained from the interviews were used to support the analysis of factors influencing material preferences. In addition, literature review and technical documentation referred to standard technical references such as SNI and ISO, academic journals, and local publications including developer brochures and area maps. A comparative analysis was also conducted using literature related to environmentally friendly building materials and Life Cycle Assessment (LCA) principles.

Data Analysis Techniques

were conducted through material categorization and evaluation of environmental friendliness criteria. Each material was classified based on several criteria, including type (structural, covering, interior, or exterior), physical properties such as weight, durability, and aesthetics, source of material (local, industrial, or natural), and sustainability potential based on literature and practical implementation. Furthermore, the materials were evaluated using five main indicators of environmental friendliness, as presented in Table 1.

Table 1. Evaluation Criteria.

Evaluation Criteria	Description
Energy Efficiency	Contribution to reducing active energy loads
Climate Resilience	Durability against tropical heat, rainfall, and humidity
Availability	Ease of access and local availability
Environmental Impact	Includes production emissions, waste, and recyclability potential
Aesthetics & Comfort	Visual perception, thermal comfort, and acoustic performance for occupants

Scores were assigned on a three-level scale: High (3), Medium (2), Low (1).

Thematic Analysis

Interview results were coded and analyzed to identify key patterns: a) Factors influencing material selection b) Challenges in material procurement c) Awareness of green materials d) Comparison between user preferences and objective material performance

Data Triangulation

Data triangulation was conducted to ensure the validity of the findings, as outlined by Yin (2000, in Nuraini, 2019; Nuraini, 2024). Validation was carried out through cross-verification of data sources (field observations, informants, literature). Triangulation also strengthens the reliability and depth of interpretation in the research results (Moleong, 2000, in Nuraini, 2019; Nuraini, 2024; Andriana & Tharo, 2018; Andriana et al., 2023).

Validity and Limitations

To ensure validity, as explained by Moleong (2000 in Nuraini, 2019; Kusumastuti et al., 2025; Nuraini, 2024), the researcher employed structured observation maps, photographic documentation and field notes with timestamps and geolocation, as well as the use of up-to-date literature sources (not older than 10 years) to compare with field findings. The limitations of this study include the absence of laboratory testing for the materials and the restricted scope, which focuses solely on a single residential area Cemara Asri. The complete research methodology process is illustrated in Figure 1 below:

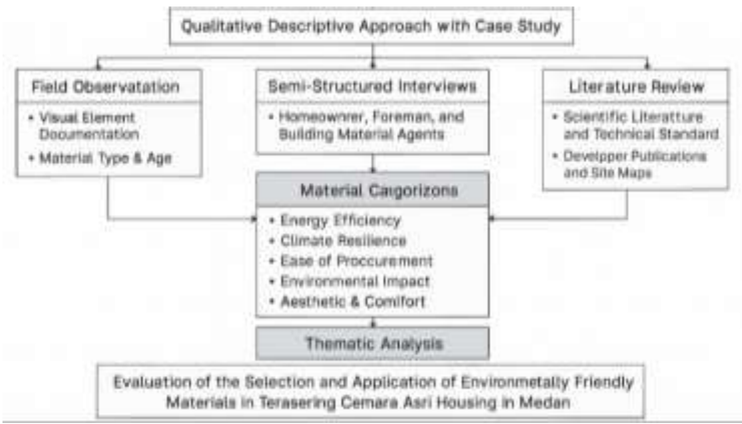


Figure 1. Research Methodology.
(Source: Author, 2025).

4. Results and Discussion

Profile of Cemara Asri Row Housing

General Characteristics of Housing Units and Residents

Cemara Asri is located on the outskirts of Medan City and is characterized as a dense residential area featuring row housing typology. Most units are built in a zero-lot configuration (side-by-side without spacing), with a building area of approximately 100 m² and a land area of about 120–150 m². Based on interviews, the majority of residents are upper-middle-class Chinese-Indonesian families who exhibit a high level of aesthetic awareness but possess limited understanding of sustainable material principles. The three case study houses observed in this research are presented in Figure 2 below:

Figure 2. Three Sample Houses Used in the Case Study.
(Source: Author's Documentation, 2025)

Building Layout and Orientation Patterns

The general layout of the buildings follows linear blocks facing either the main road or secondary alleys. Building orientation varies between east–west and north–south directions. Most row houses have limited ventilation openings at the front and rear facades, which affects air circulation and thermal comfort—particularly when the materials used do not provide adequate heat insulation. The linear arrangement of buildings along internal roads and their orientation toward the surrounding road network can be seen in Figure 3.

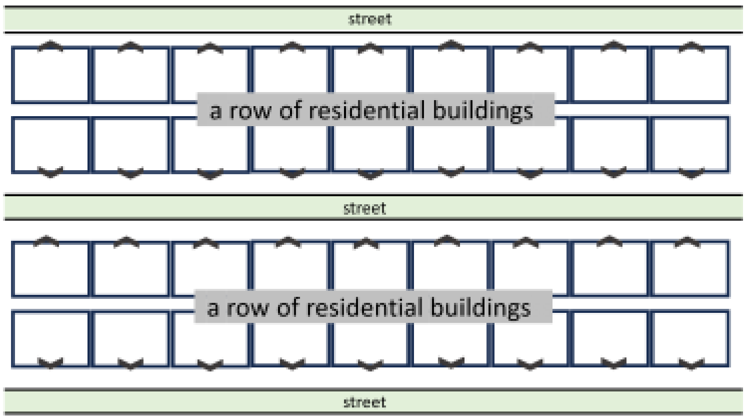


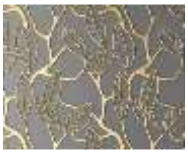
Figure 3. Layout and Orientation Pattern of Buildings in the Cemara Asri Complex.
(Source: Author's Analysis, 2025).

Identification of Building Materials

Interior Materials

Based on direct observations of three housing units, several interior materials were identified. Acoustic softboard was used on the ceilings in some houses to absorb sound and improve acoustic comfort. MDF (Medium Density Fibreboard) was applied for built-in furniture such as wardrobes and kitchen cabinets. Ceramic tiles measuring 45 × 45 cm were used as the main floor covering, while vinyl-based wallpaper was applied to the walls in living rooms and bedrooms. In addition, cork wood was found as an alternative floor covering in study areas and kitchens in two out of the three houses. A complete analysis of interior materials is presented in Table 2 below:

Table 2. Interior Material Elements.

No	Interior Material Element	Illustration	Room Name
1	Acoustic Softboard Ceiling	 	Living Room, Guest Room, Bedroom
2	Cork Wood	 	Living Room
3	Ceramic Tiles	  	Terrace, Living Room, Guest Room
4	Red Brick	 	Back Terrace, Kitchen, Storage Room
5	Tempered Glass	 	Living Room, Dining Room
6	Wallpaper	 	Guest Room, Bedroom
7	MDF (Medium Density Fibreboard)	 	Living Room, Guest Room, Dining Room, Bedroom

(Source: Analysis, 2025).

Exterior Materials

Red bricks remain the primary material used for structural walls. Concrete ventilation blocks (roster) are applied on building facades to support air circulation, although their use is limited to only a few housing units. Natural stone, particularly andesite, is utilized as exterior wall cladding to create a luxurious appearance. Large windows are constructed using tempered glass combined with aluminum frames. In addition, aluminum framing has replaced solid wood because of its greater resistance to termites and humid tropical climates. An analysis of exterior material usage is presented in Table 3 below.

Table 3. Exterior Material Elements.

No	Exterior Material Element	Illustration	Usage
1	Red Brick		All side and back walls
2	Natural Stone		Fences, Terraces
3	Aluminium		All exterior window and door frames
4	UPVC Panel		All exterior doors and windows
5	Lightweight Steel		Roof Structure
6	Clay Roof Tiles		Roof Covering
7	Concrete Ventilation Block		Drying Area, Garden Divider

(Source: Analysis, 2025)

Evaluation of Environmentally Friendly Criteria

Durability, Energy Efficiency, and Material Processing

Based on direct observation and qualitative assessment, the evaluation of sustainability criteria in the Cemara Residential Case Study was carried out using six aspects: material performance, energy efficiency, climate resilience, ease of procurement, environmental impact, and aesthetics & comfort. These criteria were scored on a three-point scale: 1 for low, 2 for medium, and 3 for high. The total score for each material is listed in the far-right column of the table. The full evaluation is shown in Table 4:

Table 4. Evaluation of Sustainable Material Criteria.

Material	Energy Efficiency	Climate Resilience	Ease of Procurement	Environmental Impact	Aesthetics & Comfort	Total Score
Red Brick	3 (High)	3	3	2	2	13
Ceramic	2	3	3	1	3	12
Clay Roof Tiles	3	3	3	3	2	14
MDF	2	2	3	1	3	11
Cork Wood	3	2	2	3	3	13

Material	Energy Efficiency	Climate Resilience	Ease of Procurement	Environmental Impact	Aesthetics & Comfort	Total Score
Concrete Vent Block	**2**	**2**	**3**	**2**	**2**	**11**
Tempered Glass	**1**	**2**	**2**	**1**	**3**	**9**
PVC Wallpaper	**1**	**1**	**3**	**1**	**3**	**9**

Scoring Scale: 1 = Low, 2 = Medium, 3 = High

Comparison Between Traditional and Modern Materials

Traditional materials such as red brick and clay roof tiles demonstrate relatively high sustainability scores due to their local availability and high durability. In contrast, modern materials like PVC wallpaper and tempered glass tend to have a higher carbon footprint and require more energy-intensive manufacturing processes, thus reducing their overall sustainability value.

Factors Influencing Material Selection

Interviews with six residents and two building material suppliers revealed several factors influencing material selection. Price was identified as the primary consideration, with materials such as red brick, ceramic tiles, and aluminum being chosen because of their stable prices and local availability. In terms of market availability, most residents preferred materials that were easily found in local building stores, even if they were not environmentally friendly. Products such as MDF and PVC wallpaper were favored due to their high accessibility. Aesthetic preference also emerged as a dominant factor, particularly in the use of natural stone and tempered glass, which were perceived as enhancing the market value of homes through their luxurious appearance, despite not always being energy-efficient. Furthermore, none of the interviewed residents mentioned Life Cycle Assessment (LCA) or sustainability as part of their material selection criteria, indicating a gap in ecological literacy that should be addressed by local governments and housing developers. Based on these findings, it can be concluded that although some materials demonstrate high sustainability potential, their use is not yet supported by adequate understanding or strategies grounded in green building principles. Economic and aesthetic considerations continue to dominate material preferences, highlighting the urgent need for education and incentives to encourage sustainable design approaches in tropical residential environments.

Discussion: Analysis Based on Literature Review Pustaka

Comparison with Scientific Literature and Best Practices

The field observation of building materials was re-evaluated and compared with findings from the following scientific literature: Traditional and Local Materials, According to Gopalakrishna & Chellappa (2022), local materials such as red bricks and clay roof tiles possess low embodied energy, as well as simple and low-emission production processes, making them suitable for tropical buildings in Southeast Asia. This aligns with the dominant use of red brick and clay tiles in Cemara Asri, which demonstrates good performance in terms of durability and sustainability. Modern Industrial Materials Based on the research by Liu et al. (2023), the use of tempered glass and aluminum indicates a high carbon footprint during production, although they offer aesthetic and structural advantages.

This is relevant to the conditions in Cemara Asri, where glass is used primarily for its visual appeal rather than sustainability considerations. Application of LCA Principles A study by Latapie et al. (2023) emphasizes the importance of implementing Life Cycle Assessment (LCA) in residential building design to identify critical points in material selection. In Cemara Asri, a systematic LCA approach has not been applied, and material selection is still largely influenced by cost and aesthetics. Developer Documentation and Site Plan an examination of brochures and site maps from the developer reveals that there are no explicit guidelines or recommendations regarding the selection of environmentally friendly building materials. The developer's focus is more on visual design, safety, and accessibility. This further supports the conclusion that sustainability principles have not yet become a priority in either the planning or construction phases of the row housing in Cemara Asri.

Implications of the Analysis

The findings indicate that traditional local materials demonstrate better sustainability performance compared to modern industrial materials. However, no specific regulations or systematic Life Cycle Assessment (LCA)-based approaches have been implemented at the level of middle-class housing developers. In addition, technical and ecological literacy regarding building materials remains low among both users and area planners. To advance toward sustainable row housing practices, several efforts are needed, including the integration of LCA principles into technical planning standards such as SNI and local regulations, education for developers and users regarding the environmental impacts of building materials, and the development of a local material catalog based on sustainability and ease of implementation.

5. Closing

This study concludes that although some materials used in the row housing complex in Cemara Asri, Medan, show potential as environmentally friendly materials—such as the use of lightweight bricks and water-based paint—their application remains partial and does not fully align with comprehensive sustainability principles. Several construction elements still rely on conventional materials that have a high environmental impact, in terms of production processes, transportation, and life cycle.

Public unawareness and economic considerations by developers are the main factors contributing to the low adoption of sustainable materials in large-scale housing projects. In addition, the absence of binding technical standards and local policies regarding the use of green materials further slows the shift toward more sustainable construction practices. Therefore, comprehensive educational and regulatory strategies are needed to enhance awareness and drive the transformation of building materials toward more environmentally friendly options.

To improve material sustainability in the housing sector, particularly in row housing developments such as in Cemara Asri, several recommendations can be considered. First, the utilization of local and natural materials should be prioritized, including nature-based and locally available materials such as wood, bamboo, cork, clay, and natural concrete ventilation blocks (roster), which have low carbon emissions and good thermal insulation performance. Research and development on alternative materials derived from organic and inorganic waste should also be encouraged. Second, education and awareness campaigns are needed through training programs and public outreach to increase awareness among communities, developers, and contractors regarding the importance of environmentally friendly materials in terms of long-term benefits and economic value. In addition, vocational and architectural education curricula should integrate topics related to green materials and sustainable development principles. Third, local governments are encouraged to establish regulations or technical guidelines regarding the use of environmentally friendly materials in housing projects and provide fiscal incentives or permit facilitation for developers implementing green construction principles, such as tax reductions, accelerated building permits (IMB/PBG), or subsidies for green building technologies. Furthermore, additional quantitative research is required to measure energy consumption, embodied energy, and carbon footprints of building materials, including the implementation of Life Cycle Assessment (LCA) to scientifically determine green material classifications. Finally, collaboration among academics, government, the private sector, and communities is essential to promote innovation and the implementation of sustainable materials in housing development.

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