Journal of Architecture and Urban Studies

Vol 3(1), 2026, 32-44
Accepted : February-20, 2026
Approved : February-21, 2026
Published : February-26, 2026

Revisiting Sustainability in Tropical Heritage Building: Architectural Lessons from Gereja Blenduk

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Abstract. The increasing level of environmental degradation has led to a decline in environmental quality, both at present and in the future. Since buildings contribute more than 30% of global emissions, building design should incorporate and implement sustainability principles. Understanding sustainability can be achieved not only through newly constructed buildings but also through the study of historic buildings. The preservation and adaptive reuse of older buildings represent an important sustainability strategy, as they maintain historical value while reducing the demand for new material resources. This study aims to analyze sustainable architectural principles in historic buildings, Gereja Blenduk as the case study. Employing a descriptive analytical research method, the findings indicate that the church reflects the application of comprehensive sustainability principles, including urban ecology, energy strategies, water management, material use, waste management, community engagement, cultural preservation, local economic strategies, and operational management. Many of these sustainability practices have developed contextually through adaptation to climate conditions, cultural values, and the social functions of the surrounding area. Therefore, Gereja Blenduk can be regarded as a tangible example of how historic buildings can adapt to sustainability principles while maintaining their authenticity.

Keywords: sustainable; historic building; tropics climate

1. Introduction

Environmental quality degradation has become a critical issue in Indonesia today. The exploitation of natural resources and environmental pollution are the primary factors contributing to the decline in environmental quality [1]–[4]. A concerning fact is that buildings contribute more than 30% of global emissions [5], [6]. This significant figure presents a major challenge for architects in designing buildings, especially as contemporary architectural design increasingly prioritizes commercial value, aesthetics, and trending styles that often attract short-term interest without adequately considering sustainability aspects, including environmental, social, and cultural contexts. Therefore, building design should incorporate and implement sustainability principles [1], [7]. The application of sustainable design should be regarded as an essential responsibility for architects to ensure that future generations can experience a healthy and livable environment. A thorough understanding of climate is fundamental in developing sustainable architectural design, as climate awareness enables architects to create designs that respond appropriately to local environmental conditions.

Learning to understand sustainable architecture can be achieved not only through newly constructed buildings and environmentally oriented design concepts, but also through the study of existing buildings, particularly historic ones. The preservation and adaptive reuse of older buildings represent an important sustainability strategy, as they help maintain historical value while simultaneously reducing the consumption of new material resources [8]–[10].

Semarang has a lot of historic colonial buildings that have survived for more than a century, particularly in the Kota Lama Semarang area. One of the iconic buildings in this

district is Gereja Blenduk, also known as GPIB Immanuel Semarang. This church has a long historical background dating back to the eighteenth century, with its initial construction occurring around the mid-1700s [11]–[13] . Its continued existence for more than one hundred years, while still functioning actively as a place of worship and regular church activities for the Christian community, provides strong evidence that historic buildings can serve as important study objects in understanding sustainable architectural principles. These include aspects such as building durability, adaptation to local climatic conditions, socio-cultural value, and the efficient use of resources through the preservation of existing structures. Therefore, studying Gereja Blenduk can contribute significantly to the development of contextually grounded sustainable architectural concepts in Indonesia.

Based on these considerations, this research aims to analyze sustainable architectural principles in historic buildings, using Gereja Blenduk as the case study object.

The term sustainable originates from the Latin sustinere, meaning to hold, support, or maintain. Various dictionaries provide multiple definitions of the term; however, its core meaning refers to the ability to preserve, support, and ensure continuity over time. Since the 1980s, the concept of sustainability has been increasingly discussed, particularly in relation to the continuity of human life on Earth. This evolving understanding has led to widely accepted definitions of sustainability and sustainable development.

Within the sustainability framework, three interconnected pillars are commonly recognized: economic, environmental, and social aspects. As environmental conditions become increasingly constrained and degradation intensifies, sustainability principles have gradually become mainstream in contemporary design approaches. This perspective aligns with the view of Harry Gordon, who argues that after decades of effort by designers, architects, individuals, and organizations, a significant shift in design thinking has occurred, with sustainability increasingly regarded as a societal design norm.

In practice, sustainable architecture is not limited to attitudes or purely technological solutions. Simon Guy emphasizes that additional critical aspects must be considered when addressing sustainability challenges. Sustainable architectural issues cannot be resolved from a single perspective; instead, a pluralistic approach is necessary to generate more innovative ideas. Therefore, environmental attitudes should remain diverse yet integrated, not uniform but unified toward shared sustainability goals.

Sustainable architecture refers to design strategies that minimize the negative environmental impacts of buildings [11]–[13]. This approach encompasses nine main principles: urban ecology, energy strategy, water management, waste management, material use, community engagement, economic strategy, cultural preservation, and operational management.

1. Urban Ecology
   Emphasizes the continuity of living ecosystems. Humans, animals, and plants are fundamentally interdependent; therefore, environmental balance must be maintained to preserve natural systems so they can continue to support present and future generations.
2. Energy Strategy
   Focuses on reducing energy consumption, reusing previously consumed energy where possible, and utilizing natural energy sources as renewable energy. Implementation may involve both technological and non-technological approaches.
3. Water
   Highlights water conservation and the optimization of water use, for example, through water recycling and reuse to improve efficiency in resource utilization.

4. Waste
   Waste generally consists of liquid, solid, and gaseous forms. Sustainable practices involve reducing waste generation, managing waste properly, and promoting recycling to minimize negative environmental impacts.
5. Material
   Material selection should consider occupant comfort and safety. Ideally, materials should be environmentally friendly, recyclable or biodegradable, non-hazardous to human health, durable, and produced through processes that minimize environmental pollution.
6. Community in Neighborhood
   Community involvement is essential for maintaining ecosystem balance across generations and for implementing sustainability values within local living environments.
7. Economic Strategy
   Economic strategies in sustainability aim to create business opportunities, particularly for small and medium enterprises (SMEs), as a means of supporting economic resilience. This contributes to local or national economic stability and self-reliance.
8. Cultural Preservation (Culture Invention)
   Culture shapes the identity and character of a society, including traditions, cuisine, and traditional architecture. As a valuable heritage, culture should be preserved and sustained for future generations while supporting broader sustainability objectives.
9. Operational Management
   Concerns occupants' understanding of building system maintenance and technology operation. Adequate knowledge among users is crucial to ensure that building systems function effectively, remain well-maintained, and support the long-term sustainability of building use.

2. Methods

This study employs a descriptive analytical method consisting of two main stages: data collection and data analysis.

2.1 Data Collection Method

Data for this research were obtained from two primary sources: primary empirical data and secondary empirical data. Primary data were collected directly through field observations of the case study object, including physical measurements of the building, visual documentation, and open-ended interviews addressing aspects of Community in Neighborhood, Economic Strategy, Cultural Preservation, and Operational Management. These primary data included measurements of spatial and building areas, identification of the number and position of ventilation openings, measurement of roof overhang dimensions and placement, and documentation of the quantity and distribution of surrounding vegetation. Secondary data were obtained through literature reviews of scientific sources, including reference books and academic journal articles. These sources were used to strengthen the theoretical framework and support the research analysis.

2.2 Data Analysis Method

The collected data were analyzed based on sustainable architecture principles outlined in the book [14]. The analytical process focused on several aspects: urban ecology, energy strategy, water management, waste management, material use, community involvement, economic strategy, cultural preservation, and operational management.

3. Results and Discussion

Gereja Blenduk is located on Jalan Letjen Suprapto No. 32, Semarang, in the Kota Lama area, which is one of the most frequently visited heritage tourism destinations in Semarang city. The building was constructed around the early nineteenth century and continues to function actively as a church for Christian worship under the administration of GPIB Immanuel Semarang. Its continued use demonstrates the building's historical resilience as well as its ongoing social and cultural relevance within the community.

Figure 1. The Location of Blenduk Church in the Kota Lama Area

Gereja Blenduk stands independently without adjoining buildings, and it is surrounded by roads on all sides. This spatial condition allows the building to be visually appreciated from multiple perspectives while also facilitating cross-ventilation from various directions, which supports passive environmental comfort.
The following section presents the findings and analysis of sustainable architectural principles observed in Gereja Blenduk.

3.1 Urban Ecology

In the context of urban ecology, sustainable architectural design seeks to harmonize built environments with natural systems to maintain environmental stability and long-term ecological resilience. The principle of sustainable urban ecology at Gereja Blenduk is reflected in the planting of vegetation around the church building. This vegetation contributes to reducing the microclimate temperature, increasing oxygen supply, and helping maintain groundwater availability in the surrounding area. The planted vegetation is regularly maintained to ensure healthy growth while preventing root systems from damaging the building structure.

Figure 2. Infiltration Zone and Vegetation Planting

The principle of sustainable urban ecology at Gereja Blenduk is reflected in the planting of vegetation around the church building. This vegetation contributes to reducing the microclimate temperature, increasing oxygen supply, and helping maintain groundwater availability in the surrounding area. The planted vegetation is regularly maintained to ensure healthy growth while preventing root systems from damaging the building structure.

3.2 Energy Strategy

Energy strategies in sustainable architecture aim to reduce energy consumption, reuse previously utilized energy, and optimize renewable energy potential through both technological and non-technological approaches [14]. In this building, energy strategies are predominantly realized through passive design approaches responsive to the humid tropical climate, considering that the church was constructed prior to the development of modern mechanical technologies.

3.2.1 Optimization of Natural Ventilation

Natural ventilation is provided through ventilation openings, including louvers (bovenlicht) and windows located on all eight sides of the building. The high interior hall further supports cross-ventilation and the stack effect, in which warmer, lighter air rises and exits through upper wall ventilation openings. This process allows cooler air to circulate in the lower occupied areas, creating a more comfortable indoor temperature [15]–[17]. This strategy significantly reduces dependence on artificial cooling systems and represents an effective form of passive energy efficiency consistent with sustainable tropical architectural principles.

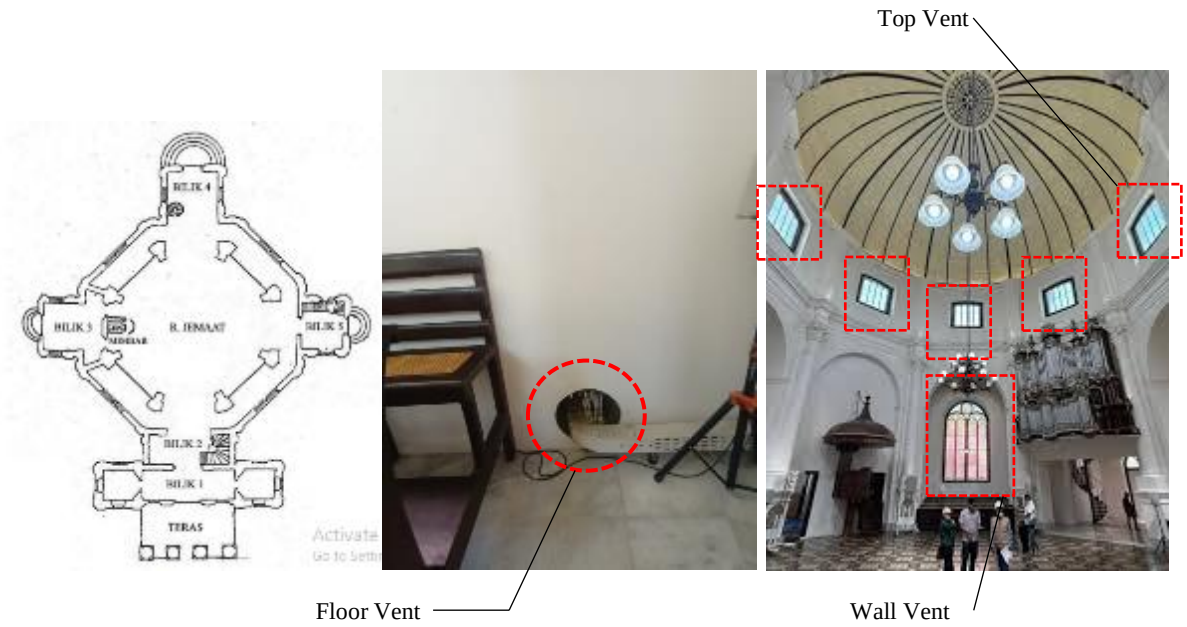

Figure 3. Ventilation Optimization to Enhance Air Circulation

3.2.2 Utilization of Natural Lighting

Large window openings on the building façade allow optimal penetration of natural daylight during the daytime. This condition reduces the need for artificial lighting while simultaneously enhancing visual comfort within the interior space. In the context of sustainable architecture, daylighting represents an important strategy for reducing electrical energy consumption and improving the overall environmental performance of buildings.

Figure 4. Utilizing Windows for Natural Lighting During Worship

Religious services at Gereja Blenduk are typically conducted between 9:00 and 11:00 a.m. (WIB) without the use of artificial lighting. Natural daylight sufficiently supports visual activities such as reading and congregational worship, demonstrating the effectiveness of passive lighting strategies in enhancing energy efficiency while maintaining visual comfort.

3.2.3 Building Mass and Materials as Thermal Barriers

The approximately 60 cm thick masonry walls, along with internal air cavities, contribute to indoor thermal stability by minimizing solar heat radiation and conductive heat transfer.

This passive thermal performance reduces reliance on modern mechanical cooling technologies and supports long-term energy efficiency, which aligns with sustainable architectural principles in tropical climates.

Figure 5. Thick Church Walls

3.2.4 Limited Dependence on Mechanical Technology

As a heritage building, Gereja Blenduk continues to maintain its original concepts of natural ventilation and daylighting. The use of mechanical systems such as air conditioning is relatively limited and typically applied only under specific conditions. This indicates that the building's energy strategy prioritizes non-technological approaches through architectural design rather than reliance on mechanical systems.

3.3 Water

As a colonial-era building located in the coastal city of Semarang, which experiences a humid tropical climate, the church was designed with a large dome roof and gutter elements that effectively channel rainwater away from the structure. This system prevents water accumulation that could damage the building while also representing a passive water management strategy adapted to local climatic conditions.

Figure 6. Dome Roof

Forty percent of the land is allocated as green open space that functions as a water catchment area. This ensures that rainwater is not immediately discharged into the city's drainage system but instead infiltrates the ground to maintain the groundwater supply. This approach aligns with sustainability principles for a better and healthier future.

3.4 Waste

Waste management at Gereja Blenduk relates to efforts to maintain environmental cleanliness within the church premises and the surrounding Kota Lama Semarang area through waste reduction, management, and reuse practices that support sustainability principles. These include: Provision of separate waste bins. Organic and inorganic waste are separated for congregants and visitors to facilitate proper management and recycling; Reduction in paper usage. Church service information and activity announcements are increasingly delivered through digital media, thereby reducing paper waste; Rainwater utilization and drainage management. Rainwater may be used for garden irrigation or outdoor cleaning purposes, helping reduce liquid waste while lowering reliance on treated water resources. During church events, the provision of single-use plastic bottled water has been discontinued. Instead, congregants are required to bring their own reusable bottles. This initiative aims to minimize plastic waste, reflecting a collective commitment to environmental sustainability

3.5 Materials

Gereja Blenduk is an eighteenth-century colonial building constructed using traditional European technologies and materials adapted to tropical climatic conditions, including thick brick masonry walls coated with lime plaster, timber roof structures, and clay roof tiles. The selection of these materials reflects not only structural strength and aesthetic considerations but also thermal comfort, indoor environmental health, and long-term sustainability.

The substantial wall mass helps stabilize indoor temperatures, while high ceilings and wooden structural elements reduce radiant heat and enhance natural ventilation, allowing interior spaces to remain relatively cool without heavy reliance on mechanical cooling systems. Furthermore, the use of natural materials such as brick, wood, and lime is generally safer for occupants because these materials contain minimal harmful chemical compounds, allow buildings to "breathe," reduce humidity and mold risk, and provide good structural resilience in tropical climates.

From an environmental perspective, these materials can be considered sustainable because they originate from natural sources, are reusable, have relatively low embodied carbon, and are often preserved or restored rather than completely replaced during conservation processes, thereby minimizing construction waste. The building's durability—having lasted for more than a century—demonstrates that traditional materials, when properly maintained, possess long service lives and ease of repair. This also reflects historical production processes that were typically simpler and generated less pollution. Consequently, this historic building represents not only architectural and cultural value but also a tangible example of sustainable material practices that remain relevant for contemporary architecture.

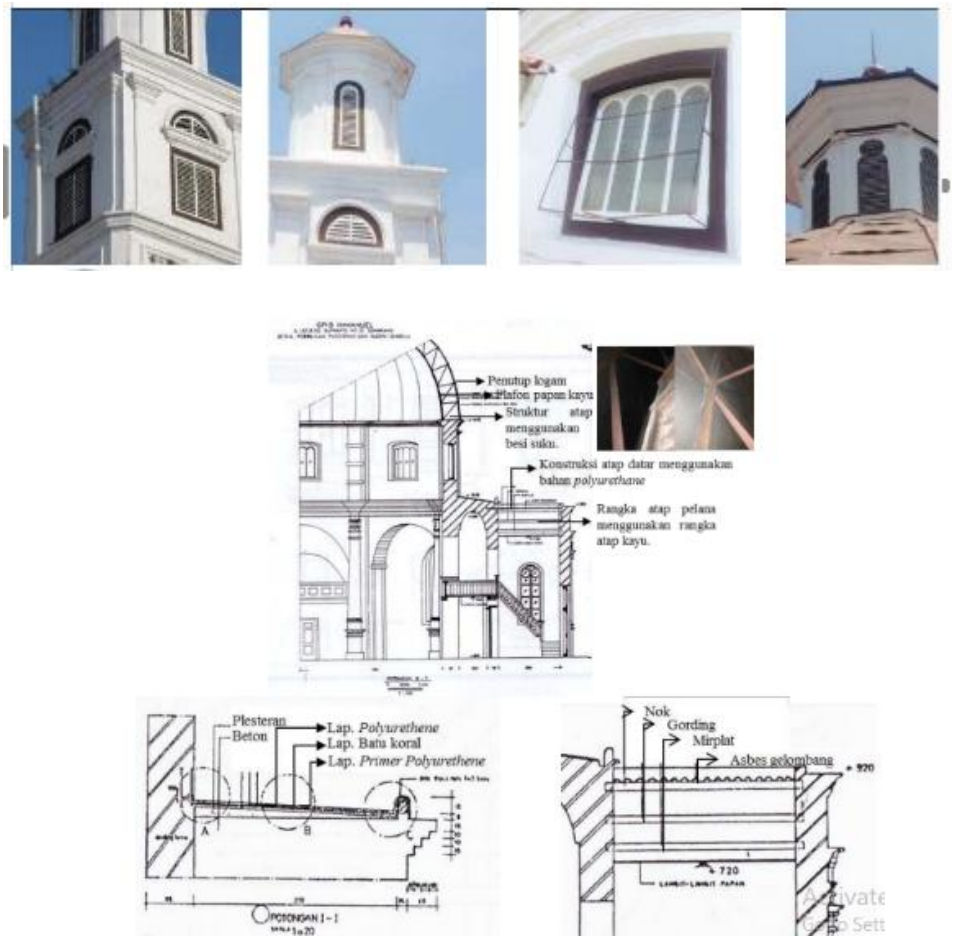

Figure 7. Roof and Wall Construction of Blenduk Church

3.6 Community in Neighborhood

Gereja Blenduk plays an important social role within the Kota Lama Semarang area and its surrounding environment. In addition to functioning as a place of worship, the church also serves as a social element that contributes to community life in Semarang. As an iconic historic building, it acts as a landmark for the district while also providing a space for social interaction among various groups, including congregants, tourists, and local residents.

The continued active use of this historic building helps preserve the identity of the area, strengthens the community's sense of belonging, and supports social and cultural sustainability. As part of the Kota Lama heritage district, the church maintains a strong relationship with its surrounding environment by supporting local economic activities, particularly heritage tourism that involves nearby residents. It also functions as a symbolic public space that reinforces social interaction and local identity, while encouraging urban revitalization, as the presence of iconic historic buildings often serves as a catalyst for preserving historic urban environments. This integration contributes to maintaining a balanced social, economic, and cultural ecosystem in the surrounding community.

Figure 8. School Group Photo

3.7 Economic Strategy

The presence of Gereja Blenduk as a heritage building and religious tourism destination in the Kota Lama Semarang area indirectly supports sustainable economic strategies by creating business opportunities for local communities, particularly small and medium enterprises (SMEs) such as culinary businesses, souvenirs, tourism services, and local creative industries. These activities strengthen the local community economy, support the sustainability of the historic district, and contribute to local economic resilience as part of sustainable development.

3.8 Cultural Preservation (Culture Invention)

The preservation of this historic building supports cultural sustainability by maintaining historical values, traditions, and the character of the built environment so they remain recognizable to future generations. The church continues to function both as a place of worship and as a historical tourism destination in Semarang, allowing religious culture, colonial architectural heritage, and surrounding community social activities to be preserved and transmitted sustainably. This is reflected in several aspects:

3.8.1 Revitalization of the Kota Lama Semarang Area

The preservation of the church as an iconic historic building encourages conservation efforts for other colonial-era buildings nearby, helping maintain the historical atmosphere of the district while preventing the loss of its original identity.

3.8.2 Historical and Architectural Education

The building is frequently used as a study object by students, researchers, and educational tourism groups. Through these activities, knowledge about history, architecture, and local culture continues to be introduced to younger generations.

Figure 9. Group Photo Collages

3.8.3 Sustainable Cultural and Religious Activities

Various activities such as regular worship services, church music concerts, and cultural events in the surrounding area contribute to maintaining spiritual traditions while strengthening the cultural identity of the local community.

3.9 Operational Management

The congregation of Gereja Blenduk has established a dedicated church maintenance team responsible for operational management in accordance with heritage building conservation principles. This team is also tasked with disseminating knowledge about building maintenance, material conservation, and facility management to both congregants and the wider community. These efforts reflect a continuous commitment to preserving the building's function, comfort, and long-term sustainability while ensuring the conservation of its historical value.

Figure 10. Cleaning the Church Area

Maintenance activities, including cleaning of Gereja Blenduk and its surrounding environment, are carried out regularly through collective voluntary efforts by members of the congregation. This communal participation supports the building's upkeep while fostering social cohesion and shared responsibility for heritage preservation.

Table 1. Implementation of Sustainability Principles at Blenduk Church

No	Principles	Remark
1	Urban ecology	implemented
2	Urban ecology	implemented
3	Energy strategy	implemented
4	Water management	implemented
5	Waste	implemented
6	Material use	implemented
7	Community involvement	implemented
8	Economic strategy	implemented
9	Cultural preservation	implemented

Table 1 shows that all nine sustainability principles, including urban ecology, energy strategy, water management, waste management, material use, community involvement, economic strategy, cultural preservation, and operational management, have been implemented in the observed Blenduk.

4. Conclusion

Based on the analysis of the implementation of the nine sustainability principles at Gereja Blenduk in Semarang, it can be understood that this heritage building not only holds historical and architectural value but also demonstrates strong relevance to sustainable architecture concepts. Aspects of urban ecology, energy strategy, water management, material use, waste management, community involvement, cultural preservation, local economic strategy, and operational management indicate the presence of sustainability practices that have largely developed contextually through adaptation to climate, culture, and the social functions of the area.

The presence of the church within the Kota Lama Semarang district also contributes to social and economic sustainability by strengthening local identity, supporting heritage tourism activities, and creating economic opportunities for surrounding communities. Furthermore, the principles of cultural preservation and historic building management demonstrate that architectural conservation can align with environmental and social sustainability efforts when supported by appropriate operational management. Therefore, Gereja Blenduk can be regarded as a tangible example of how historic buildings can adapt to sustainability principles without losing their authenticity.

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