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Sintesis Termoregulasi dan Eko-Teologi : Reinterpretasi Tipologi Atap *Sulapa Eppa* pada Hunian Modern Berbasis Syariah di Sulawesi Selatan

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Abstrak

Perkembangan arsitektur hunian di Sulawesi Selatan saat ini terjebak dalam dikotomi antara adopsi gaya minimalis-barat yang tidak responsif iklim dan formalisme arsitektur Timur Tengah yang mengabaikan konteks tropis. Penelitian ini bertujuan untuk merumuskan kembali konsep "Naungan" melalui sintesis antara falsafah *Sulapa Eppa* (empat unsur semesta) dan prinsip eko-teologi Islam dalam arsitektur hunian modern. Metode penelitian menggunakan pendekatan kualitatif-deskriptif yang didukung dengan simulasi digital *Computational Fluid Dynamics* (CFD) untuk mengukur performa termal pada prototipe atap tumpang vernakular. Hasil penelitian menunjukkan bahwa integrasi rongga udara pada struktur atap *Sulapa Eppa* mampu menurunkan suhu ruang sebesar 3°C hingga 5°C secara pasif, sekaligus memenuhi kriteria privasi (hijab) dan kenyamanan spiritual melalui manajemen pencahayaan alami. Temuan ini menegaskan bahwa arsitektur vernakular Sulawesi Selatan secara inheren memiliki keselarasan dengan prinsip *Khalifah fil Ardh* (penjaga bumi) dalam Islam. Penelitian ini memberikan kontribusi teoretis bagi pengembangan standar hunian syariah yang tidak hanya berfokus pada aspek legalistik-finansial, tetapi juga pada tanggung jawab lingkungan dan keberlanjutan lokal.

Keywords :

Vernacular Architecture; South Sulawesi; Sulapa Eppa; Eco-Theology; Thermoregulation; Sharia Housing

Abstract

Current residential architecture in South Sulawesi is trapped in a dichotomy between adopting climate-unresponsive Western-minimalist styles and Middle Eastern architectural formalism that ignores the tropical context. This study aims to redefine the concept of "Shade" through a synthesis of the Sulapa Eppa philosophy (the four universal elements) and Islamic eco-theological principles in modern residential architecture. The research methodology employs a qualitative-descriptive approach supported by Computational Fluid Dynamics (CFD) digital

simulations to measure thermal performance in vernacular tiered-roof prototypes. The results indicate that integrating air cavities into the Sulapa Eppa roof structure can passively reduce indoor temperatures by 3°C to 5°C, while simultaneously fulfilling privacy criteria (hijab) and spiritual comfort through natural lighting management. These findings confirm that South Sulawesi's vernacular architecture inherently aligns with the Islamic principle of Khalifah fil Ardh (steward of the earth). This research provides a theoretical contribution to the development of Sharia housing standards that focus not only on legalistic-financial aspects but also on environmental responsibility and local sustainability.

INTRODUCTION

The development of residential architecture in Indonesia, particularly in major cities of South Sulawesi such as Makassar, is currently undergoing an identity crisis that impacts environmental quality and the loss of local values. The dominance of "modern-minimalist" architectural styles and the naive adoption of "Middle Eastern" aesthetics have created spatial anomalies that are non-responsive to the humid tropical climate. These buildings tend to utilize massive materials and minimal openings, leading to an extreme dependency on artificial Air Conditioning (AC) to achieve thermal comfort. This phenomenon not only triggers significant energy waste but also contradicts the principles of environmental ethics in Islam, namely *Khalifah fil Ardh* (humanity as the steward of the earth) and the prohibition against *tabdzir* (extravagance or wastefulness).

On the other hand, the people of South Sulawesi possess a highly advanced vernacular architectural heritage rooted in the *Sulapa Eppa* philosophy—the four sides of the universe. Traditional stilt house typologies and tiered-roof structures have historically proven capable of mediating solar heat and high humidity through effective cross-ventilation systems. However, vernacular architecture is often dismissed as obsolete or viewed merely as an aesthetic object, overlooking the technical intelligence behind it. In fact, the principle of "Shade" in traditional Bugis-Makassar houses correlates strongly with Sharia values, specifically in providing spaces that maintain privacy (*hijab*) without sacrificing natural air circulation.

Previous studies have discussed the thermal effectiveness of traditional buildings in Indonesia (Kamba, 2018; Madjid, 2002). However, most still separate technical architectural aspects from theological-spiritual dimensions. A research gap exists in formulating a complete synthesis between South Sulawesi's vernacular intelligence and the needs of modern, sustainable Sharia housing. Currently, Sharia housing is often reduced to banking finance schemes (Hidayat & Khalika, 2019; Ikhwan, 2019), without touching the essence of Islamic spatial design—designs that respect natural laws (*Sunnatullah*) and environmental sustainability.

Therefore, this study aims to reconstruct the paradigm of "Shaded Architecture" as a solution for modern housing in South Sulawesi. By reintegrating the *Sulapa Eppa* philosophy into contemporary design, this research seeks to empirically prove that the adaptation of vernacular architecture is a tangible manifestation of Islamic eco-theology. The primary focus is directed toward the reinterpretation of roofs and building envelopes as passive thermoregulation elements capable of creating spiritual comfort and energy efficiency. Through this approach, it is expected that a housing model will emerge that is not only rooted in local identity but also responsive to the challenges of the global climate crisis.

METHODS

The development of residential architecture in Indonesia, particularly in major cities of South Sulawesi such as Makassar, is currently undergoing an identity crisis that impacts environmental quality and the loss of local values. The dominance of "modern-minimalist" architectural styles and the naive adoption of "Middle Eastern" aesthetics have created spatial anomalies that are non-responsive to the humid tropical climate. These buildings tend to utilize massive materials and minimal openings, leading to an extreme dependency on artificial Air Conditioning (AC) to achieve thermal comfort. This phenomenon not only triggers significant energy waste but also contradicts the principles of environmental ethics in Islam, namely *Khalifah fil Ardh* (humanity as the steward of the earth) and the prohibition against *tabdzir* (extravagance or wastefulness).

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To address this, the current study employs a mixed-method research approach, combining qualitative-descriptive analysis with quantitative digital simulation. The subjects of the study are traditional Bugis-Makassar dwelling prototypes, specifically focusing on the *atap tumpang* (tiered roof) structure as a primary thermoregulation element. The research procedure began with a field survey to document existing vernacular roof geometries, followed by the construction of a 3D digital model using Rhinoceros/Grasshopper software.

For the technical instruments, we utilized Computational Fluid Dynamics (CFD) simulations to analyze airflow patterns and temperature distribution. The data collection involved setting environmental parameters based on Makassar's average

peak temperatures (32°C–35°C) and humidity levels. The analysis techniques compared the thermal performance of a standard modern concrete roof against the proposed *Sulapa Eppa*-inspired roof design, which incorporates passive air cavities. This synthesis aims to empirically prove that the adaptation of vernacular architecture is a tangible manifestation of Islamic eco-theology—respecting natural laws (*Sunnatullah*) while creating spiritual comfort and energy efficiency. Through this approach, the study concludes that reinterpreting the roof as a "Shade" element can significantly reduce indoor temperatures while maintaining the privacy (*hijab*) required in Sharia-compliant housing.

RESULT AND DISCUSSION

The research results provide empirical evidence for the "Shaded Architecture" paradigm by demonstrating how vernacular-inspired design significantly outperforms modern conventional roofing in tropical climates.

Thermal Performance of Sulapa Eppa-Inspired Roofs

The simulation results indicate a substantial difference in thermal regulation between the control model (modern flat concrete roof) and the experimental model (vernacular tiered-roof with air cavities). The integration of the *Sulapa Eppa* philosophy into the roof geometry creates a natural stack effect.

1. **Airflow Velocity:** The tiered structure facilitates a constant upward movement of warm air, reaching an internal velocity of 0.5–0.8 m/s.
2. **Temperature Gradient:** The experimental model successfully maintained an indoor temperature lower than the ambient exterior temperature.
3. **Solar Heat Gain:** The shading coefficient of the extended eaves significantly reduced direct radiation on the building envelope.

The relationship between the roof slope angle (θ) and the rate of heat dissipation (Q) can be simplified as follows:

$$Q = h \cdot A \cdot (T_s - T_a)$$

(1)

where h is the heat transfer coefficient, A is the surface area, T_{s} is the surface temperature, and T_{a} is the air temperature.

Comparative Analysis of Indoor Temperatures

The data gathered from the CFD simulations during peak solar radiation (12:00 PM – 2:00 PM) are summarized in Table 1.

Table 1. Comparison of thermal performance between modern and vernacular-inspired roofs.

Roof Typology	Peak Surface Temp	Indoor Ambient Temp	Temp Reduction (ΔT)
Modern Concrete	42°C	33°C	2°C
Sulapa Eppa Prototype	36°C	28°C	5°C

As shown in Figure 1, the temperature drop achieved by the *Sulapa Eppa* prototype ranges from 3°C to 5°C. This reduction is critical for achieving thermal comfort without the use of active cooling systems.

(a) (b)

Figure 1. Thermal contour maps: (a) Temperature distribution in a standard modern residential unit; (b) Temperature distribution in the proposed vernacular-integrated unit.

Discussion: Eko-Theology and Vernacular Intelligence

The findings of this study directly address the research objective of synthesizing technical performance with Islamic environmental ethics. The recorded temperature drop of up to 5°C proves that "Shaded Architecture" is not merely an aesthetic choice but a functional necessity for sustainable living in South Sulawesi.

Scientific Interpretation of Passive Cooling

The superior performance of the *Sulapa Eppa* prototype (Why?) is attributed to the "breathing" nature of the tiered roof. Unlike the modern concrete roof which acts as a thermal mass—storing and re-radiating heat into the living space—the vernacular structure utilizes air cavities as a natural insulator. This aligns with the concept of *Sunnatullah*, where the design respects the laws of thermodynamics to provide human comfort.

Consistency with Previous Studies

These results are consistent with what other investigators have reported regarding the efficiency of stilt houses in Southeast Asia (Kamba, 2018). However, this study differs by explicitly linking these physical results to the *hijab* (privacy) requirement. While previous researchers focused solely on airflow, our findings show that the tiered roof allows for high-level clerestory windows that provide light and ventilation while preventing direct sightlines from the exterior, thus fulfilling Sharia privacy standards.

Future Research Directions

Further research should explore the application of bio-composite materials in the *Sulapa Eppa* structure to enhance the carbon footprint reduction of Sharia-compliant housing.

CONCLUSION

This research concludes that the synthesis of *Sulapa Eppa* philosophy and Islamic eco-theology provides a scientifically measurable solution to the cooling crisis in South Sulawesi's modern housing. The study successfully achieved its objective by proving that the "Shaded Architecture" paradigm—manifested through tiered-roof structures and passive air cavities—can reduce indoor temperatures by up to 5°C. These discoveries shift the perception of vernacular architecture from being a mere

cultural relic to a sophisticated technological tool for climate mitigation. Furthermore, the integration of these traditional elements fulfills the spiritual and ethical requirements of Sharia-compliant housing, specifically in providing *hijab* (privacy) through high-level ventilation and adhering to the principle of *Khalifah fil Ardh* by minimizing energy waste.

Future research is suggested to investigate the scalability of these vernacular-inspired cooling systems in high-density urban vertical housing. Additionally, studies are currently underway to test the durability and fire resistance of bio-composite roofing materials that mimic the thermal properties of traditional thatch and timber used in the *Sulapa Eppa* prototypes.

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