PhD Theses

Integrating Traditional Woodcarving Techniques with Contemporary Construction: Enhancing the Energy Efficiency of Traditional Malay Houses

By:
Noor Roziana Binti Abdul Rahim

University of Sopron
Faculty of Wood Engineering and Creative Industries
Sopron
Year 2025

PhD Theses

Integrating Traditional Woodcarving Techniques with Contemporary Construction: Enhancing the Energy Efficiency of Traditional Malay Houses

By:

Noor Roziana Binti Abdul Rahim

Supervisors:
Dr. Szabó Péter
Prof. Dr Zsolt Kovács

University of Sopron

Faculty of Wood Engineering and Creative Industries

Sopron

Year 2025

Introduction

Approximately one-fifth of the planet's surface, characterised by hot and humid climates, is home to one-third of the world's population. As a result, the reliance on HVAC (heating, ventilation, and air conditioning) systems has surged to manage indoor comfort in these challenging climates, accounting for approximately 68% of the total energy consumption in residential and service sectors (Orme, 2001). Despite energy conservation efforts by industrialised nations, the increased use of HVAC systems often leads to higher energy consumption and negative environmental impacts. NV (natural ventilation), achieved through passive design strategies, is a viable alternative to artificial climate control. However, modern buildings depend heavily on mechanical ventilation (Chan et al., 2013).

Malay vernacular architecture offers a sustainable approach to NV, utilising multiple windows, building orientation, roof design, and multi-level floors to enhance thermal comfort (Rizal et al., 2021). With their intricate woodcarving, traditional Malay houses demonstrate an inherent understanding of NV and thermal comfort. Woodcarvings on fascia boards, door leaves, and ventilation panels contribute functionally and aesthetically, allowing for airflow and light penetration while creating visual interest through intricate patterns (Kamarudin & Said, 2008). In contemporary contexts, integrating traditional woodcarvings into modern architecture is often limited to symbolic uses rather than functional applications.

This research addresses the gap in integrating traditional woodcarving techniques to enhance energy efficiency in modern buildings. It will analyse wind patterns in traditional Malaysian houses, such as Rumah Limas Hutan Bandar and Rumah Tok Su, focusing on how woodcarving ventilation panels influence airflow and indoor comfort. The study will evaluate ventilation performance using ASHRAE Standard 55. The research will also conduct a climatic analysis of Szombathely, Hungary, examining wind speed and temperature during the summer. Drawing inspiration from the Szekely Gate, the study will explore the integration of traditional Hungarian woodcarvings into contemporary architectural designs in Szombathely. The study will also compare the effects of these woodcarving ventilation panels with opened vents, closed vents, and mechanical ventilation. CFD (Computational Fluid Dynamics) simulations will be employed to evaluate the impact of these

woodcarvings on passive ventilation in a house model, considering Johor and Szombathely's unique climate conditions.

Problem Statement

Despite the potential of traditional woodcarving techniques to contribute to sustainable and energy-efficient building design, their integration into modern construction still needs to be improved. In traditional Malay houses, intricate woodcarvings are decorative and serve functional purposes, promoting NV and enhancing energy efficiency. Similarly, Hungarian architecture, notably the Székely Gate, incorporates woodcarvings with potential applications in contemporary design. However, modern construction practices often overlook these techniques, resulting in a disconnect between sustainable design approaches and the preservation of cultural heritage in both Malaysian and Hungarian contexts. Current research fails to adequately explore how these traditional woodcarvings can optimise energy performance in modern architecture, leaving their potential untapped. There is a pressing need for in-depth studies investigating how traditional woodcarving techniques from diverse cultural traditions can be effectively integrated into contemporary construction to improve energy efficiency while preserving cultural identity.

Research Objectives & Research Questions

Research Objective 1 (RO1): To investigate the critical architectural elements of Malay traditional houses that contribute to enhanced ventilation performance and to examine the impact of architectural woodcarvings on this performance.

Research Question 1 (RQ1): What architectural elements of Malay traditional houses significantly improve ventilation performance, and how do architectural woodcarvings influence this performance?

Research Objective 2 (RO2): To evaluate the impact of various environmental conditions and climates on the effectiveness of woodcarvings as passive ventilation devices using CFD simulation.

Research Question 2 (RQ2): How do different environmental conditions and climates affect the effectiveness of woodcarvings as passive ventilation devices?

Research Objective 3 (RO3): To compare the performance of woodcarving panels with fully open vents, closed vents and mechanical ventilation using CFD simulations.

Research Questions 3 (RQ3): How do woodcarving ventilation panels perform compared to fully open vents, closed vents and mechanical ventilation systems based on CFD simulation results?

Research Objective 4 (RO4): To develop guidelines for integrating woodcarving into modern construction practices to achieve sustainable, energy-efficient, and culturally preserving building designs.

Research Question 4 (RQ4): What key considerations and best practices are essential for integrating woodcarving into modern construction to ensure sustainable, energy-efficient, and culturally preserving building designs?

Hypotheses

The strategic integration of traditional woodcarvings in contemporary architecture enhances ventilation performance by optimising natural airflow. This integration contributes to sustainable and energy-efficient building practices aligned with key design elements and environmental conditions.

Research Methodology

The methodology chapter introduces the approaches used to explore the role of traditional woodcarvings in enhancing NV and thermal comfort within different climatic contexts. The research integrates several methods, including a literature review, site visits, wind analysis, microclimate analysis, and CFD simulations, all aimed at understanding the impact of woodcarving on architectural designs. The literature review focuses on Rumah Tok Su, providing historical insights into traditional Malay architecture. In contrast, the site visit to Rumah Limas Hutan Bandar MBJB, a traditional Malay house, offers practical observations on woodcarving ventilation in a contemporary setting. The research further incorporates wind analysis for Johor Bahru and a microclimate analysis for Szombathely, Hungary, using Climate Consultant 6.0 to assess environmental

conditions such as wind speed and temperature. Airflow analysis is conducted using Autodesk CFD to evaluate air circulation through the woodcarving ventilation panels. It compares their performance with fully opened vents, closed vents, and mechanical ventilation, and it investigates the influence of airflow and thermal comfort within a basic house setup. By integrating these diverse methods, the research creates a comprehensive framework for incorporating traditional woodcarving into modern architectural designs, enhancing both functionality and cultural significance while considering modern ventilation solutions.

Literature Review

This literature review examines existing research on using woodcarving ventilation panels to enhance NV in architecture, focusing on traditional and modern applications. The study emphasises woodcarvings' historical and cultural significance in Malay and Hungarian architecture, evaluating their functional and aesthetic roles in building design.

Traditional woodcarvings in Malay architecture, particularly in Rumah Limas and Rumah Tok Su, are notable for their functional role in promoting passive cooling and cross-ventilation. Carved panels, typically placed above windows and doors, facilitate airflow and help regulate indoor temperatures. These elements also preserve privacy and embody cultural symbolism. Studies have shown that these woodcarvings can significantly improve ventilation without compromising the building's overall thermal comfort (Azman et al., 2022; Mohamad Ba'ai et al., 2022; Nik Hassin & Misni, 2023). In contrast, Székely gates in Hungarian architecture are not designed for airflow. They are monumental wooden structures rich with symbolic meaning, often placed at the entrance of traditional Székely homesteads. These gates feature intricate relief carvings depicting motifs that reflect cultural identity, beliefs, and local heritage (Bárth, 2023). While they do not serve a ventilative function, their design principles, such as using natural materials, craftsmanship, and cultural expression, offer valuable inspiration for integrating heritage elements into modern architectural design.

Integrating carved panels in modern architecture has been explored by applying biomimetic designs inspired by natural patterns. These designs, such as patterns mimicking elephant skin, are being tested

for their potential to enhance airflow and improve building thermal performance (Hays et al., 2024). CFD simulations have supported the notion that carved openings in panels can influence internal air movement. Factors such as motif design and perforation ratio play a crucial role in optimising ventilation.

Despite these advancements, there is a gap in research regarding the use of carved panels for natural ventilation in non-tropical climates, particularly in regions like Hungary. While there is a growing interest in energy-efficient and passive ventilation strategies, limited studies have explored the practical application of carved panels in temperate climates. This study addresses this gap by investigating how traditional woodcarving panels can enhance natural ventilation in both tropical and temperate climates. By focusing on the influence of these panels on airflow and thermal comfort, the research aims to contribute to integrating cultural heritage in modern architecture, supporting energy efficiency, and cultural continuity.

Results and Conclusion

1. **Effectiveness of Traditional Design:**

    - Traditional Malay houses, particularly Rumah Tok Su and Rumah Limas Hutan Bandar MBJB, showcase the functional benefits of woodcarving ventilation systems. These designs significantly improve air movement control, contributing to indoor thermal comfort within the ASHRAE comfort zone. The woodcarving panels prove effective in regulating temperature and promoting even airflow distribution throughout the building, reflecting the potential of traditional designs in achieving passive cooling.

2. **Airflow Dynamics:**

    - CFD simulations revealed that the intricate woodcarving patterns create multiple airflow pathways, promoting effective air mixing and turbulence. Compared to opened and closed vents, the woodcarving panels exhibit a more balanced air distribution, ensuring air velocity is moderate enough to maintain comfortable indoor conditions. These simulations also showed that woodcarving ventilation

systems contribute to even temperature regulation across the building, further enhancing comfort levels. While providing more control over airflow, mechanical ventilation systems can disrupt the intended passive ventilation patterns created by the woodcarving panels.

3. **Integration with Modern Standards:**

    - The research demonstrates that traditional woodcarving ventilation systems can be successfully adapted to meet modern comfort requirements. Combining traditional design principles and contemporary building standards shows promising potential for integration into modern architectural practices, especially in climates that demand natural cooling strategies.

4. **Cross-Cultural Applicability:**

    - The principles derived from Malay woodcarving ventilation systems have broader applicability across diverse cultural and climatic contexts. The study also explored cross-cultural design integration by incorporating traditional Hungarian motifs into modern structures in Szombathely, Hungary, showcasing the global potential of this approach to NV. This cross-cultural exploration underscores the relevance of traditional design principles in diverse architectural contexts worldwide.

Theses and Related Publications

Thesis 1 (Functional Benefits of Woodcarving Ventilation Systems in Traditional Malay Houses): Traditional Malay houses, particularly Rumah Tok Su and Rumah Limas Hutan Bandar MBJB, showcase the functional benefits of woodcarving ventilation systems. These designs significantly improve air movement control, contributing to indoor thermal comfort within the ASHRAE comfort zone. The woodcarving panels prove effective in regulating temperature and promoting even airflow distribution throughout the building, reflecting the potential of traditional designs in achieving passive cooling.

Related Publications:

Abdul Rahim, N. R. B., & Kovács, Z. (2024). Cultural Preservation Meets Modern Design: Investigating the Impact of Traditional Woodcarvings on Natural Ventilation in Johor, Malaysia. In Wood 4 Sustainability (pp. 131–149). https://doi.org/10.35511/978-963-334-541-2-14

Abdul Rahim, N. R. B., & Szabó, P. (2023). THE ROLE OF WOODCARVING AS A NATURAL VENTILATION IN PASSIVE COOLING STRATEGIES OF TRADITIONAL MALAY ARCHITECTURE: A CASE STUDY OF RUMAH LIMAS HUTAN BANDAR, JOHOR BAHRU. XXVI. Tavaszi Szél Konferencia 2023, 540–554. https://m2.mtmt.hu/api/publication/36096188

Abdul Rahim, N. R. B., & Szabó, P. (2025). Woodcarving in Malay Architecture: Patterns, Structures and Cultural Significant. Built Environment Journal (BEJ). https://m2.mtmt.hu/api/publication/36057971

Thesis 2 (CFD Simulations and Airflow Analysis of Woodcarving Panels): CFD simulations revealed that the intricate woodcarving patterns create multiple airflow pathways, promoting effective air mixing and turbulence. The panels' high FAR allows substantial airflow while moderating air velocity to ensure comfortable indoor conditions. This capability highlights the effectiveness of traditional carvings in facilitating natural ventilation without the need for mechanical cooling.

Related Publications:

Abdul Rahim, N. R. B., & Kovács, Z. (2025). Comparative Air Flow Analysis Between Johor and Szombathely: Evaluating Woodcarving Ventilation Panels. ACTA SILVATICA ET LIGNARIA HUNGARICA: AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES. https://m2.mtmt.hu/api/publication/35930307

Seidu, H., Brougui, M., Abdul Rahim, N. R. B., & Németh, R. (2024). EVALUATION OF DYNAMIC AND STATIC MODULI OF ELASTICITY OF HYBRID EUCALYPTUS WOOD FROM

DIFFERENT LOCATIONS IN GHANA. WOOD RESEARCH, 69, 132–142. https://doi.org/10.37763/wr.1336-4561/69.1.132142

Thesis 3 (Adapting Traditional Woodcarving Ventilation Systems for Modern Comfort Standards): The research demonstrates that traditional woodcarving ventilation systems can be successfully adapted to meet modern comfort requirements. Combining traditional design principles and contemporary building standards shows promising potential for integration into modern architectural practices, especially in climates that demand natural cooling strategies.

Related Publications:

Abdul Rahim, N. R. B., & Szabó, P. (2023). THE ROLE OF WOODCARVING AS A NATURAL VENTILATION IN PASSIVE COOLING STRATEGIES OF TRADITIONAL MALAY ARCHITECTURE: A CASE STUDY OF RUMAH LIMAS HUTAN BANDAR, JOHOR BAHRU. XXVI. Tavaszi Szél Konferencia 2023, 540–554. https://m2.mtmt.hu/api/publication/36096188

Abdul Rahim, N. R. B., & Szabó, P. (2025). Woodcarving in Malay Architecture: Patterns, Structures and Cultural Significant. Built Environment Journal (BEJ). https://m2.mtmt.hu/api/publication/36057971

Thesis 4 (Cross-Cultural Integration of Woodcarving Ventilation Systems in Hungary): The principles derived from Malay woodcarving ventilation systems have broader applicability across diverse cultural and climatic contexts. The study also explored cross-cultural design integration by incorporating traditional Hungarian motifs into modern structures in Szombathely, Hungary, showcasing the global potential of this approach to natural ventilation.

Related Publications:

Abdul Rahim, N. R. B., & Kovács, Z. (2024). Cultural Preservation Meets Modern Design: Investigating the Impact of Traditional Woodcarvings on Natural Ventilation in Johor, Malaysia. In Wood 4 Sustainability (pp. 131–149). https://doi.org/10.35511/978-963-334-541-2-14

Abdul Rahim, N. R. B., & Kovács, Z. (2025). Comparative Air Flow Analysis Between Johor and Szombathely: Evaluating Woodcarving Ventilation Panels. ACTA SILVATICA ET LIGNARIA HUNGARICA: AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES. https://m2.mtmt.hu/api/publication/35930307

Thesis 5 (Hybrid Ventilation Systems Combining Traditional and Modern Approaches): This research paves the way for developing hybrid ventilation systems that combine traditional passive cooling methods with modern technological advancements. Such systems could offer a sustainable solution by leveraging traditional knowledge and modern technology, addressing the growing demand for energy-efficient and comfort-oriented buildings.

Related Publications:

Abdul Rahim, N. R. B., Julaila, A. R., & Rajabi, A. R. (2019). A STUDY ON THE SIGNAGE SYSTEM IN MELAKA, THE UNESCO HERITAGE SITES. Journal of Architecture, Planning and Construction Management, 1, 22. https://m2.mtmt.hu/api/publication/35896748

Abdul Rahim, N. R. B., Szabó, P., & Kovács, Z. (2024a). Natural Ventilation Technique in Traditional Dwellings: A bibliometric Analysis of Research Trends. EVERGREEN. https://m2.mtmt.hu/api/publication/35444866

Abdul Rahim, N. R. B., Szabó, P., & Kovács, Z. (2024b). OPTIMIZING NATURAL VENTILATION FOR SUSTAINABLE ARCHITECTURE: A COMPREHENSIVE STUDY ON WIND-DRIVEN HOUSE ORIENTATION STRATEGIES IN SZOMBATHELY, HUNGARY. XXVII. Tavaszi Szél Konferencia 2024 - Absztraktkötet, 383. https://m2.mtmt.hu/api/publication/35896212

References

1. Azman, N. S., Mazlan, I. M., Sujak, I., Mat So'od, N. F., & Wallen, L. (2022). Traditional Malay House in Negeri

Sembilan: Cultural influence in design and construction. *Environment-Behaviour Proceedings Journal*, *7*(21). https://doi.org/10.21834/ebpj.v7i21.3775

2. Bárth, J. (2023). Öröklődő elköteleződések és jogosultságok a székely közösségekben. In *Élő jogszokások: Jogi néprajzi, jogtörténeti és jogi kultúrtörténeti tanulmányok*. https://doi.org/10.15170/jkjnk11-kpvk-2023-03
3. Chan, S. C., Che-Ani, A. I., & Nik Ibrahim, N. L. (2013). Passive designs in sustaining natural ventilation in school office buildings in Seremban, Malaysia. *International Journal of Sustainable Built Environment*, *2*(2), 172–182. https://doi.org/10.1016/j.ijsbe.2014.01.002
4. Hays, N., Badarnah, L., & Jain, A. (2024). Biomimetic design of building facades: an evolutionary-based computational approach inspired by elephant skin for cooling in hot and humid climates. *Frontiers in Built Environment*, *10*. https://doi.org/10.3389/fbuil.2024.1309621
5. Kamarudin, Z. B., & Said, I. (2008). COMPOSITION OF MALAY WOODCARVING: CASE STUDIES ON TWO TRADITIONAL TIMBER HOUSES. In *Ismail Said Jurnal Alam Bina* (Vol. 11, Issue 2).
6. Mohamad Ba'ai, N., Aris, A., Khairi, H., & M.Hum, Y. D. (2022). Malay Traditional Motifs Character in Jewellery Design. *Asian Journal of Environment-Behaviour Studies*, *7*(23). https://doi.org/10.21834/aje-bs.v7i23.413
7. Nik Hassin, N. S. F., & Misni, A. (2023). The Evaluation on Thermal Performance of Rumah Negeri Sembilan Berserambi Dua dan Beranjung. *International Journal of Built Environment and Sustainability*, *10*(2). https://doi.org/10.11113/ijbes.v10.n2.1054
8. Orme, M. (2001). Estimates of the energy impact of ventilation and associated financial expenditures. *Energy and Buildings*, *33*(3). https://doi.org/10.1016/S0378-7788(00)00082-7
9. Rizal, K., Ismi, I., Azli, A., Izzati, A., & Julaihi, W. (2021). A review on Malay vernacular architecture ventilation design elements effectiveness and its application comparative case study: Rumah Kutai Tiang 12 (vernacular) and Rumah Selangorku (contemporary). *AIP Conference Proceedings*, *2347*. https://doi.org/10.1063/5.0051639