Sustinere
Journal of Environment and Sustainability
Volume 9 Number 1 (2025) 111-118

Print ISSN: 2549-1245 Online ISSN: 2549-1253
Website: https://sustinerejes.com E-mail: sustinere.jes@uinsaid.ac.id

RESEARCH PAPER

Revitalization of nipa thatch as sustainable roofing material at Balikpapan Nature School

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Article history:
Received 10 October 2024 | Accepted 8 April 2025 | Available online 2 Mei 2025

Abstract. Nipa as thatch roofing material originates from leaves of nipa palm tree (*Nypa fruticans*). Although nipa has a long history in Southeast Asia, it has gradually been replaced by other materials. Nature school (sekolah alam), a relatively new education model established in Indonesia in 1998, offer a different approach to school facilities, one of which is the use of open-air classroom buildings. Balikpapan Nature School, located in island of Borneo, is one of many institutions developing the nature-based school concept. The school has adopted the Dayak Kenyah longhouse design, incorporating nipa thatch roofing in its buildings. However, one of the buildings has had its nipa roofing replaced with bitumen. This research investigates the heat gain characteristics of nipa roofing as a sustainable material in comparison to bitumen roofing. Analysis of the observational data using paired *t*-test shows a significant difference, with nipa roofing effectively reducing heat gain. These supports findings support previous studies that have identified nipa as an environmentally friendly material capable of providing better thermal comfort in humid tropical climates.

Keywords: Nipa; thatch roof; sustainable; nature school.

1. Introduction

1.1. Origin of nipa

Nipa roofing is a type of thatch material, also known in Indonesia as *rumbia* (Kaamin et al., 2013; Rumiati & Prasetyo, 2013). It is a plant-based material made from nipa palm leaves of nipa palm (*Nypa fruticans*) (Djamaluddin et al., 2023). *Rumbia* can also be made from the leaves of the sago palm (*Metroxylon spp*), both of which are mangrove palm species commonly found in wet tropical areas (Mulyati & Sarwadi, 2011). According to Steger (2023), thatched roofs are typically made from three types of plants: grass-like, palm-like, and other. Of the 250 plant species used for thatching across 60 countries, the three most common types in Indonesia are: *alang-alang* (from grass-like plants); nipa (from palm-like leaves); and sugar palm fiber (*ijuk*), which is derived from the fiber of the sugar palm tree (*Arenga pinnata*) (Steger, 2023).

As a member of the mangrove family, *Nypa fruticans* thrives in wetlands across equatorial regions. It prefers freshwater, muddy environments, such as river mouths and banks, that are still influenced by tides (UNEP-WCMC, 2025). According to Rahman et al. (2024), the natural distribution of nipa extends from Bengal Bay to Southeast Asia, with a significant presence in the

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DOI: https://doi.org/10.22515/sustinere.jes.v9.i1/441

Indonesian archipelago. Nipa is highly tolerant of both freshwater and brackish environments and often forms green belts along riverbanks (Widodo et al., 2020).

However, mangrove deforestation around the world has reached an alarming rate of 1% per year, with an estimated 30% loss in the late 20th century (UNEP-WCMC, 2025). The highest rate of mangrove deforestation occurs in Southeast Asia, especially in Indonesia, where mangrove loss has been reported as 0.05 million hectares per year (Djamaluddin et al., 2023).

1.2. Nipa as construction material in Southeast Asia

The use of nipa as roofing material is widespread in Indonesia and vernacular architecture throughout Indonesia. In Malaysia, many kampong houses that once used nipa thatch roofs have since been replaced by corrugated metal, concrete tile, or corrugated concrete roofing. While these modern materials are effective in terms of durability, they are also strong heat conductors. In contrast, more sustainable materials such as nipa are more effective at reducing heat (Kaamin et al., 2013). Historically, all traditional Malay buildings in the Riau region used nipa thatch roofing. However, in recent developments, especially office buildings, modern roofing materials such as tin and clay roof tiles have become more common (Malik, 2012).

In the heart of Sumatra, nipa roofing was used for important structure. The Pematangsiantar Mosque, built in 1911, originally features wooden posts, wood plank walls, and a nipa thatched roof, with no doors or windows. Over time, the mosque evolves to its present form (Ginting & Anita, 2020). A similar is seen at the Wapauwe mosque in Ambon, Maluku. Established in 1414, this mosque was relocated several times during Dutch colonization due to security concerns before settling at its current site. Despite undergoing multiple renovations, the mosque retained its original form. In 1997, its corrugated metal roof was replaced with nipa thatch, restoring its histirical appearance. Wapauwe mosque is now recognized as one of the oldest mosques in Indonesia that still retains its traditional architectural style (Astuti, 2018).

In South Sumatra, nipa shingles are also used as wall coverings. This can be observed in the *Lamban Tuha* house, the traditional house of the Ranau communities in Ogan Komering Ulu District, and in houseboats along the Musi River (Wazir, 2018). In the Philippines, nipa leaves are widely used as thatch and shingles for roofing and walling rural houses. Production occurs regularly every 2-3 months. In the three months following Typhoon Yolanda, one NGO received enough nipa shingles from Bohol (Philippines) to construct 100 shelters per week. Bohol is one of the oldest nipa shingles-producing regions in the country, along with Mindanao and Tacloban (Carandang et al., 2009).

Nipa roofing is also found in Thailand, Where the government has encouraged the cultivation of nipa palms on abandoned shrimp farms. Like in the Philippines, nipa thatch in Thailand is used for both roofing and walling. A 2020 report noted a high demand for nipa roofing. However, in Thailand, nipa palms are more commonly used for producing molasses and vinegar (Cheablam & Chanklap, 2020).

Victoria et al. (2017) reported that nipa palm thatch can reduce heat gain due to its permeable nature, which allows heat to escape freed buildings. Similarly, another study showed that palm thatch leaf roofing offers better thermal comfort in humid tropical climates (Kindangen et al., 2024). Kindangen et al. (2024) used a Quick Thermal Conductivity Meter (QTM-710) to measure the temperatures of two types of thatch leaves compared to zinc-based tin roofing. The study was conducted a specifically constructed roof model and focused on sago and sugar palm leaf roofing.

In contrast to Kindangen's et al. (2024) model-based approach, this study compares the heat-reducing capability of nipa thatch roofing with that of bitumen roofing. Importantly, this research was conducted on two fully functional buildings rather than experimental models.

1.3. Nipa use at Sekolah Alam Balikpapan

The study was conducted at Balikpapan Nature School (*Sekolah Alam Balikpapan*), one of many institutions practicing nature-based education in Indonesia. Located in Balikpapan, East

Borneo, the school was established in 2008 and currently offers three levels of education: kindergarten, elementary, and junior high. It is situated in a moderately contoured valley covering an area of 9,000 m^2. The school uses wooden stilt buildings as classrooms, with most roofs made of nipa thatch, locally sourced in Balikpapan area.

The school itself is a member of the Indonesia Nusantara Network of Nature Schools (*Jaringan Sekolah Alam Nusantara*, JSAN). The nature school model emerged in 1998 as an alternative form of education in Indonesia. According to Husnan, chairman of JSAN, there are an estimated 500 schools across the country that identify as *sekolah alam*, with approximately 230 of them being active members (Anggota Jaringan Sekolah Alam Nusantara, n.d.).

The two buildings observed in this study are modeled after Dayak Kenyah vernacular architecture, specifically, wooden stilts longhouse. The materials used are consistent with those traditionally used in Dayak Kenyah house; all posts and beams are made of *ulin* wood, a hardwood native to Borneo, also known as ironwood. Unlike traditional Dayak Kenyah houses, which typically use *ulin* wood shingles for roofing, the school buildings use nipa thatch. However, studies have shown that while Dayak Kenyah houses on the Indonesian side of Borneo often used wood, the Malaysian side frequently employ thatch roofing made from palm leaves (Victoria et al., 2017). Nipa thatch is considered more economical, costing less than Rp 2,000 (approximately 13 cents in 2023) per shingle (Prayitno, 2021). This type of vernacular architecture is seen as a good model for sustainable design due to its use of locally available materials, local labor, and traditional construction techniques Oliver, 2006).

One of the most distinctive architectural features of *sekolah alam* is the open-air classroom, in contrast to enclose buildings typically found in conventional schools. Safar (2021) notes that most modern enclosed classrooms in Indonesia are now equipped with air conditioners. In contrast, *sekolah alam* institutions generally use open-air wooden or bamboo stilt buildings as learning shelters, such as the one shown in Figure 1, which allow students to interact freely with the natural environment (Safar, 2021). In that sense, the architecture of these schools aligns with the principles of sustainable design, emphasizing the use of locally resourced, environmentally friendly materials. These building types provide excellent air circulation and natural lighting, resulting in minimal energy consumption. This study aims to provide positive input for *sekolah alam* institutions by supporting their architectural choices as sustainable and contextually appropriate solutions.

Figure 1. Classroom building at Sekolah Alam Balikpapan with nipa thatched roof covered with netting

2. Material and method

Nipa thatch shingles are made from mature leaves taken from the lower branches of the plants, as these leaves are more rigid and less brittle, making them preferable in size and durability compared to shingles made from younger leaves. Practice in the Philippines have shown that nipa roofing can last up to 10 years, provided the leaves are properly harvested, treated, stored, maintained, and installed in double layers. A minimum roof pitch of 40 degrees is also recommended. Termite treatment is essential and can be done either by applying protective paint or by soaking the nipa leaves in salt water for half a day. In some regions, the shingles are smoked before installation. To protect the roof against strong winds, metal ridge caps, barge caps, and fish nets are often laid over the nipa shingles.

On Bangka Island in Indonesia, harvested nipa leaves are traditionally soaked in the river for one or two weeks to increase their durability. The leaves are then folded in half, and a small bamboo or wooden stick is inserted between them to form the core of the shingles. This core, called *bengkawan*, functions as the roof batten. The leaves are then stitched with nylon or plastic thread to secure the *bengkawan* in place. Each nipa shingle typically measures approximately 1.5 to 1.8 meters in length.

In contrast, in the Wuawua District of Kendari, organic thread made from the bark of sago leaf stems is used instead of nylon. This natural thread is called *resam*. Other artisans use threads made from scrubs and bushes (Umar & Arsyad, 2017). In other parts of Indonesia, such as among the Bajo community, thread made from bamboo bark, known as *gala*, is used (Umar et al., 2018). These studies detail the step-by-step process of making nipa roof shingles, from harvesting to final assembly. Based on these findings, this study hypothesizes that nipa thatch offers a better roofing solution due to its lower thermal conductivity compared to bitumen roofing.

This study was conducted at Sekolah Alam Balikpapan, a nature-based school that primarily uses wooden stilt buildings with nipa thatch roofs. Data collection involves observing and measuring the surface temperatures of nipa palm leaves and bitumen roofing. Both the top and bottom surfaces of each material were measured. Measurements were taken at approximately the same time each day over a 14-day period, using a consistent spot on each surface to ensure data accuracy. A greater discrepancy between the top and bottom surface temperatures indicate better heat resistance, implying that less heat is transferred into the interior space, resulting cooler room conditions.

The collected data were first analyzed to calculate the surface temperature difference between the upper and bottom surfaces using the Equation 1:

$$\textit{Temperature difference} = \textit{Top surface temperature} - \textit{Bottom surface temperature} \qquad (1)$$

These temperature differences were then analyzed using a two-tailed Student's *t*-test in SPSS software to determine whether the differences between the two materials were statistically significant.

3. Result and discussion

The study builds on literature suggesting that palm leaf roofing, as a sustainable material, provides better thermal comfort in tropical buildings due to its ability to reduce heat gains. It further explores how to quantify this benefit by comparing palm leaf roofing to a fabricated material, i.e., bitumen roofing. Both materials were installed side by side on adjacent buildings at Sekolah Alam Balikpapan (indicated by 'x' in Figure 2).

The building with bitumen roofing was previously covered with nipa thatch. To reduce maintenance costs, the nipa thatch was replaced with corrugated bitumen sheets. During interviews, the teachers assigned to this classroom reported that the temperature under the bitumen roof felt higher than it had under the nipa roof. Additionally, bitumen roofing creates a darker indoor environment compared to nipa thatch.

An observation was conducted to assess the thermal conductivity of both nipa thatch and bitumen roofing. Measurements were taken on 14 nonconsecutive days at approximately the same time, around 1.00 p.m, to ensure consistent sunny conditions with the sun near its peak position. A thermometer gun, shown in Figure 3, was used to manually measure the temperature of the top and bottom surfaces of the nipa thatch and corrugated bitumen roofing.

Figure 2. Aerial photo of Sekolah Alam Balikpapan, bitumen roofing (red) and nipa roofing (brown)

(a) (b)

Figure 3. (a) Temperature gun and (b) view of the measurement on the bottom surface of nipa

The observation data (Table 1) indicate that although the top surface temperatures of nipa roofing may be higher, its bottom surface temperatures are consistently lower than those of bitumen roofing. The bottom surface temperatures of the nipa thatch differ only slightly from the ambient air temperature at the time of measurement. On average, the top surface temperature of the bitumen roofing was 5°C higher than that of the nipa thatch. These data were further analyzed to calculate temperature differences, as shown in Table 2.

Table 1. Temperature measurement results.

Day	Date	Time	Air Temp.	Nipa Thatch		Bitumen	
				Bottom	Top	Bottom	Top
1	18-Sep-23	12:41	34	32.4	49.5	35.2	43.5
2	19-Sep-23	12:57	34	31.7	47.3	34.2	40.4
3	22-Sep-23	12:56	31	30.4	45.7	43.5	45.6
4	25-Sep-23	12:49	33	31,5	53.4	42.5	52.9
5	26-Sep-23	12:42	32	31.7	54.8	43.3	58.6
6	27-Sep-23	12:54	31	32.6	53.5	44.8	55.7
7	04-Oct-23	12:54	31	31.9	45.2	43.9	54.1
8	05-Oct-23	12:43	32	32.7	49.9	44.5	53.4
9	06-Oct-23	12:50	32	32.3	45.1	41.4	51.3
10	09-Oct-23	12:53	32	32.8	51.2	46.3	59.1
11	10-Oct-23	12:39	32	32.3	48.1	43.2	51.4
12	11-Oct-23	12:45	31	31.3	45.9	40.8	48.3
13	12-Oct-23	12:39	31	32.0	54.5	46.5	57.2
14	13-Oct-23	13:01	29	31.4	46.5	44.1	54.3

Table 2. Temperature difference between top and bottom surfaces.

Day	Date	Temperature Difference	
		Nipa	Bitumen
1	18-Sep-23	17.1	8.3
2	19-Sep-23	15.6	6.2
3	22-Sep-23	15.3	2.1
4	25-Sep-23	21.9	10.4
5	26-Sep-23	23.1	15.3
6	27-Sep-23	20.9	10.9
7	04-Oct-23	13.3	10.2
8	05-Oct-23	17.2	8.9
9	06-Oct-23	12.8	9.9
10	09-Oct-23	18.4	12.8
11	10-Oct-23	15.8	8.2
12	11-Oct-23	14.6	7.5
13	12-Oct-23	22.5	10.7
14	13-Oct-23	15.1	10.2

Table 2 shows the temperature differences between the top and bottom surfaces of nipa thatch, ranging from 15.30°C to 23.10°C. For bitumen roofing, the difference range from 2.10°C to 15.30°C. On average, the temperature difference for nipa thatch is 17.40°C, while for bitumen roofing it is only 9.40°C. In other words, nipa thatch can retain 26% to 50% of the heat, resulting in a thermal conductivity rate of 50% to 74%. This means only 50% to 74% of the heat received on top of surface is conducted to the bottom. In contract, bitumen has a higher thermal conductivity rate, ranging from 65% to 94%.

In a comparative analysis, the data show that nipa thatch outperforms bitumen in terms of thermal performance. The heat received on top of surface of the nipa thatch is not fully transferred to the bottom surface, resulting in a significantly cooler interior environment. This supports the perception of the teachers assigned to the bitumen-roofed classroom who reported that indoor temperature felt higher than in the nipa thatched room.

Further data analysis using a two-tailed Student's t-test in SPSS software supports this finding, with a *p*-value of less than 0.001, indicating high significance. With an alpha level of 0.005, it can be concluded that nipa thatch provides better thermal comfort due to its lower heat transfer capacity.

These results further support Victoria's (2017) description of thermal properties of nipa palm thatch in reducing heat gain. Similarly, Kindangen et al (2024)noted nipa thatch has thermal characteristics comparable to sugar palm and sago palm leaves, making them viable alternatives to modern fabricated roofing materials. It is also worth noting that this study was conducted in an open-air building without walls or partitions. Therefore, the results specifically highlight the heat retention properties of nipa thatch.

4. Conclusion

Nipa has long been a primary choice for roofing material among communities in Southeast Asia. Although its use has gradually declined, it is still applied in several important structures, such as the Wapauwe mosque and many vernacular buildings. Based on the experiment conducted at Sekolah Alam Balikpapan, nipa thatch offers several advantages as a roofing solution. The data demonstrate that nipa provides better thermal comfort due to its low thermal conductivity. Additionally, it is a sustainable roofing option for humid tropical regions, being both affordable and locally available. However, this study focuses on only one aspect: demonstrating that nipa thatch results in lower heat gain, which in turn enhances the building's thermal comfort.

Despite the increasing popularity of factory-made materials, this study highlights that nipa thatch continues to offer benefits. It remains a sustainable material, as it is naturally sourced, though it is becoming less abundant due to global mangrove deforestation. The decision of the nature school to preserve vernacular architectural methods, as seen in the practices at Sekolah Alam Balikpapan, is commendable and should be supported. Further research is recommended on the durability is often cited as drawback. A deeper understanding on how to improve or reinforce nipa thatch may lead to its acceptance and use once again.

Acknowledgment

The author of this article would like to express gratitude to the Director of Sekolah Alam Balikpapan for allowing the study to be conducted there. This article is also supported by the Master of Architecture Program at the Universitas Pendidikan Indonesia.

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