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Physical Elements of Heritage Buildings: Study of the Kadariah Palace in Pontianak City, West Kalimantan

Elementy fizyczne obiektów zabytkowych. Studium pałacu Kadariah w mieście Pontianak w zachodnim Kalimantanie

Keywords: Pałac Kadariah, element fizyczny, architektura malajska, konstrukcja drewniana

Słowa kluczowe: Kadariah Palace, physical element, Malay architecture, wooden structure

Introduction

Malay architecture has a vital characteristic in its use of wood as building materials. The use of wood is related to local socio-cultural and environmental factors [Hoseini and Dahlan 2012]. The characteristics of wood used in the structures (generally hardwood species) include long durability [Andi and Sudradjat 2016], and these structures can stand for up to hundreds of years [Kassim et al. 2020]. Although wood, as a material, is solid and durable, a diminution in wood quality can occur, such as through damage, stains, decay, or weathering if continuously exposed to biotic and abiotic damage factors [Zabel and Morrell 2020].

The Kadariah Palace, as one of many distinguished historical buildings, signifies the vanguard of other structures, which must be protected and preserved as part of the memory of the establishment of Pontianak City [Anwar 2014]. The Kadariah Palace displays the characteristics of traditional Malay architecture with the acculturation of Dutch Colonial and Middle Eastern cultures [Kassim et al. 2020]. Preservation considers the state of physical objects. Documentation is one of the explications

in conservation and preservation efforts for these objects, accomplished by recording images, photos, videos, interviews, or developing virtual reality [Zain 2014].

Researchers have not further explained the current condition of the physical elements of the heritage buildings under study. Previous research conducted on the Kadariah Palace [Kassim et al. 2020] explained the palace's characteristics, parameters, and general structure, but they did not further explain the condition of wooden structural elements in the Kadariah palace. A study was also conducted on the wooden heritage structure elements. This research aims to identify the physical condition in order to provide an idea of the necessary physical restoration of the building as a conservation effort [Anwar 2014]. Another study conducted on the Kadariah Palace was focused more on the facade of the building [Hamzah 2011]. Wood can change its structure and strength due to decay or weathering, damage, and stains. Wood rot is a change in cell walls with a decrease in the usefulness of wood in a slow process due to biotic (microorganism activity) and abiotic (chemical activity) factors, characterized by discoloration culminating in physical destruction of the wood [Zabel and Mor-

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Fig. 1. Zoning of the Kadariah Palace for research analysis; by N. Norita.
Rys. 1. Podział pałacu Kadariah na strefy do analizy badawczej; opr. N. Norita.

rell 2020]. Damage to wood is caused by two sources: biotic and abiotic damage, especially when the wood is wet [Reinprecht 2016]. A color change indicates stains or wood stains, and a pattern is found on the surface of the wood fibers [Pournou 2020] which is characterized by excessive bending of the wood [Zabel and Morrell 2020]. Biological damage or biodegradation of wood is damage that occurs due to the activities of living things, including fungi and insects [Reinprecht 2016]. Reinprecht [2016] further explained that the types of wood damage are divided into three types: rots, wood dyes, and stains and molds. Wood rot fungi are divided into brown rot, white rot, and soft rot [Singh and Singh 2014]. Insect species that attack wood, in general, are termites and beetles [Feci et al. 2013]. Meanwhile, non-biological damage is damage caused by the interaction of wood with the environment, such as weather, thermal, mechanical, and chemical factors [Zabel and Morrell 2020].

Consequently, this study requires complete data about the Kadariah Palace's physical elements, with the scope of structural elements (foundations, floors, columns, beams, walls, and roofs), non-structural elements (doors, windows, ventilation, and stairs), and ornamental elements. The physical condition of biological factors is influenced by fungi and insects and non-biological factors such as weather, thermal, mechanical, and chemical factors. Therefore, the authors carried out this research to identify and complete data on the physical elements of the Kadariah Palace in Pontianak City and present a comprehensive explanation of the current condition of the palace regarding the physical elements related to the wooden heritage structure.

Methodology

The historical and cultural heritage of Malays in West Kalimantan is widespread throughout the island, as can be seen from the heritage of the palaces in all districts or cities. There are twenty-three Islamic sultanates in the historical records of the sultanates in the province

of West Kalimantan [Firmanto 2012]. Traditional Malay design as an evolutionary form of the Malay lifestyle can be identified through the physical elements of the building [Nor and Isa 2015].

Heritage structural elements are characterized by structural connections in transferring the overall load of the building [Riggio et al. 2018]. Pavlovskis et al. [2019] say that structurally, the physical structure can be composed of elements of floors, columns, beams, walls, and roofs, while according to Zain and Fajar [2014], the structural elements of a building are divided into three parts, namely:

- a. The lower structure (substructure) consisting of foundations and beams.
- b. The middle structure (bottom side superstructure) consisting of girders, floors, frames, walls, and stiffening beams.
- c. The upper structure (upper side superstructure) consisting of girders and heavy floors, attic walls, and the truss and roof.

The non-structural heritage elements consist of windows and doors, room dividers, architectural facades, and balconies, according to Pavlovskis et al. [2019], while according to Nor and Isa [2015], non-structural elements include doors, windows, roofs, walls, stairs, and spread screens.

Massive wood with high variability is generally used in historical building structures [Riggio et al. 2018]. Buildings with wooden structures can reach ages measured in hundreds of years if appropriately designed [Asdrubali et al. 2017]. Ironwood is known as a typical plant of Kalimantan [Hairah et al. 2017], predominantly used as the main structure that supports the overall load of the building because it belongs to the strong wood class I and durability class I [Kamaluddin et al. 2020]. Ironwood also has water resistance and extended durability [Andi and Sudradjat 2016].

The Kadariah Palace is located in the settlement area of Kampung Beting, Dalam Bugis Sub-district in Pontianak City, West Kalimantan. The research variables

were divided into dependent variables (structural elements, non-structural elements, decorative ornaments) and independent variables (biological and non-biological damage). The observation unit of physical elements consists of structural elements (foundations, floors, columns, and beams), non-structural elements (doors, windows, roofs, walls, stairs, and house cliff screens), and decorative ornament elements (lattices and finials).

Field observations were carried out using visual survey methods and close-range photogrammetry methods. According to Rodrigues et al. [2011] and Lestari [2013], the visual survey method can be used to analyze the damage that occurs to the external components of the building. The close-range photogrammetric method collects historical architectural data objects and their elements through documentation and models [Pavlovskis et al. 2019]. The visual survey method used a Nikon D7200 DSLR camera, an iPhone 7 mobile phone camera, and a GoPro Hero 8 Black to take photo documentation. In contrast, the close-up photogrammetry method used a Nikon 7200 DSLR camera and a DJI Mavic Air 2 drone. Photo data using drones were taken at an altitude of 9–60 m above ground level.

The obtained primary data of some digital captures, i.e., aerial photos in the form of .jpg images from the close-range photogrammetry method with the Agisoft Metashape Professional, was processed in the following stages:

- Align photos (.jpg) taken from drones and DSLR cameras in high quality,
- Set up a low-quality dense “cloud build,”
- Set “build mesh” with low-quality,
- Set the “build texture” according to the display settings of the Agisoft software.

After the above steps, the 3D model would be converted into 2D views. The result would show the screenshots to the building’s front, left, and top views (structural, non-structural elements, and wooden decorative ornaments). To refine the images of screenshots, objects were then processed utilizing Adobe Photoshop.

The data was analyzed with a descriptive qualitative approach from the completion of the observed survey documentation and textured 2D modeling data process. The data was categorized into groups based on the deterioration characteristics, and then examined using the literature comparative study method—the comparative conducting to the visual capture on the wood surface. In contrast, interview data was used as complementary data, thus supporting the literature study.

Results and discussion

Physical elements such as structural elements, non-structural elements, and decorative ornaments [Nor and Isa 2015] are the components of the Kadariah Palace building. These elements will be described in three parts of the building, namely the front side (A), the left side (B), and the back side (C) (see Fig. 1.).

A. Structural elements

Physical component foundations, floors, columns, and beams are found as structural elements of the building in the Kadariah Palace [Pavlovskis et al. 2019]. On the front part of the building in section A, as shown in Fig. 2b–d, a snapshot of the floor, beam, and column elements is visible in the front view (Fig. 2a). The foundation elements (Fig. 2e) can be seen through the lattice gaps. The columns that stand are very distinctive from the European style because they still maintain the previous Dutch building designs. In section B, the column elements are in clear view on the rear side building section as shown in Fig. 2f), and the columns are seen along the palace front hall (see Fig. 2g). On closer examination, the floor and beam elements (see Fig. 2h) and foundations can be seen in Fig. 2i.

On the rear part of the building in section C (Fig. 3a), the physical elements of the columns, beams, and floors of the building follow the pattern of the building’s shape. The foundation elements (Fig. 3b) are visible through the ground frame screen. Overall, the Kadariah Palace building consists of three structural parts (Fig. 3c): the substructure, bottom side superstructure, and upper side superstructure. The sub-structure includes the foundation (Fig. 3d), the bottom side superstructure includes floor beams, girders, and walls (Fig. 3e), and the upper side superstructure includes stiffeners and roof trusses [Zain and Fajar 2014].

The Kadariah Palace building was constructed with hardwood materials, beginning with the foundation, floors, columns, and beams (according to information, the palace was established without any combination of other types of wood). The choice of belian wood material is due to its sturdy and long-lived nature; it can last for hundreds of years [Kassim et al. 2020], as evidenced by the age of the Kadariah Palace itself, which has reached the age of 213 years. Belian wood is an original species from Kalimantan [Hairah et al. 2017], strengthening the regionality and locality of the Kadariah Palace building, which characterizes Malay architectural principles [Kadir et al. 2018].

B. Non-structural elements

Non-structural elements complement structural elements such as doors, windows, roofs, walls, stairs, and screen spread that complete the palace building [Nor and Isa 2015]. Based on observations, in section A, a number of visible doors on the front of the first-floor building can be accessed directly through the front porch; there are eight small double doors and one large double main door (Fig. 4a). There is one main stair as access from the palace courtyard to the building (Fig. 4b), and there are two stairs as access to the second floor (Fig. 4c). The house screen cliff is also seen to complement the front side of the palace building, and made of belian wood (Fig. 4d).

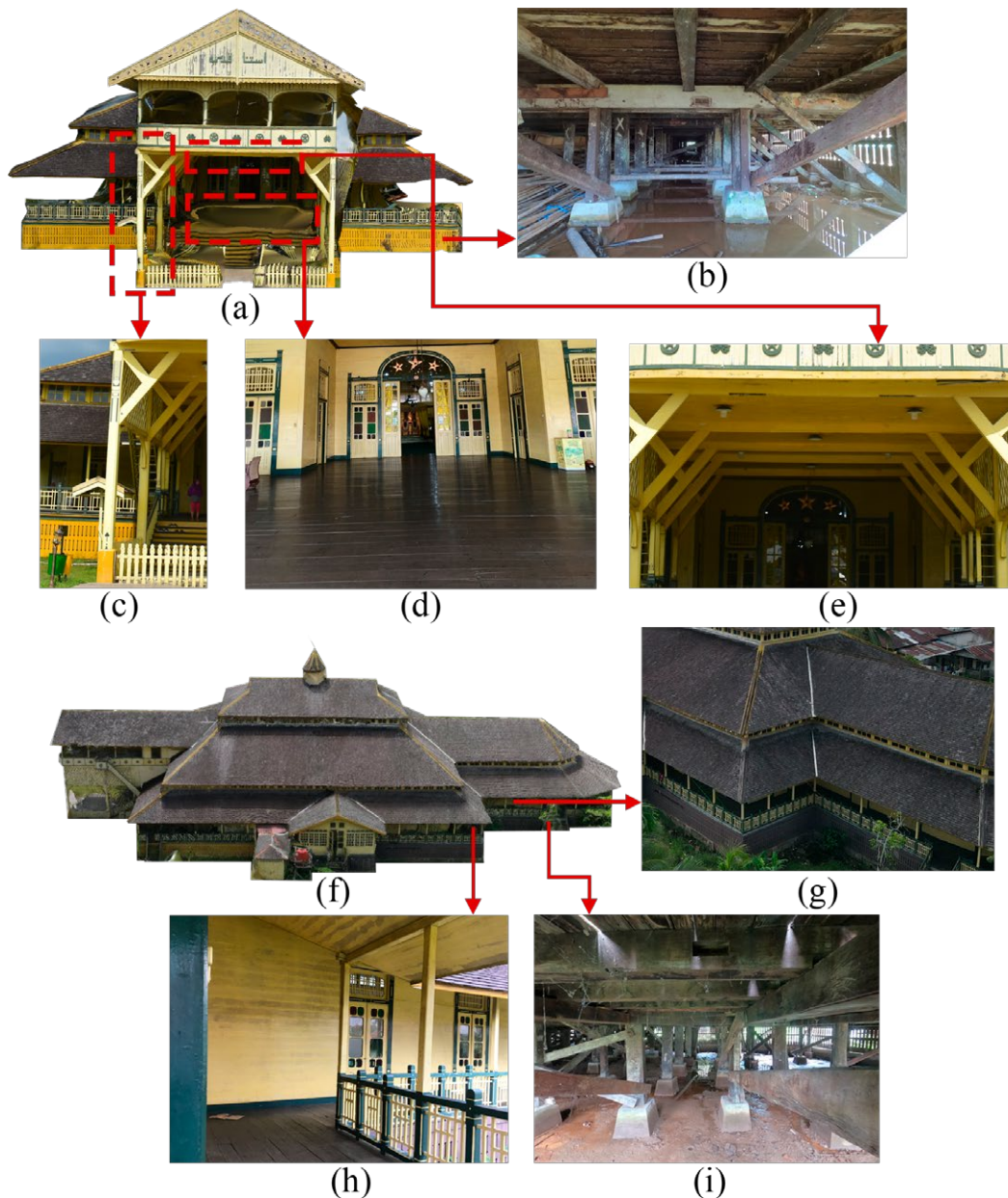


Fig. 2. Physical components of Kadariah Palace in section A and B; photo by N. Norita 2021.
Rys. 2. Fizyczne elementy pałacu Kadariah w sekcji A i B; fot. N. Norita 2021.

In section B, the left side of the building, are installed seven small twin doors (Fig. 5a–b). The second floor of the Kadariah Palace building is fitted with windows around the walls (Fig. 5c). On the left side of the building, there are three stairs that provide access to the palace (Fig. 5d).

On the rear side of the building in section C, there are two small double doors (Fig. 6a) and some windows which also are found enclosed on the second floor (Fig. 6b), with one stair as circulation access from the back yard of the building (Fig. 6c).

The style of the doors and windows of the Kadariah Palace still shows a typical Dutch design. Each door is equipped with a vent right above it. All small doors on the front, left, and back of the building have the same size and design style. Doors, windows, and ventila-

tion use wood materials. The same applies to the materials used for stairs, walls, and screen spreads. The roofing material is wood shingles. The dominant non-structural elements are coated in yellow and trimmed with green.

C. Decorative ornament elements

According to Nor and Isa [2015], at least sixteen types of decorative ornamental elements can be found in Malay architectural buildings. Ornaments as decorations can show cultural symbols, both norms and community characteristics, or contain messages to be conveyed [Hamzah and Indriana 2020]. In part A, there are several decorative ornaments, such as stairs lattices depicting a clove motif (Fig. 7a), fence lattices with a geometric motif (Fig. 7b), ornamental sculptured col-

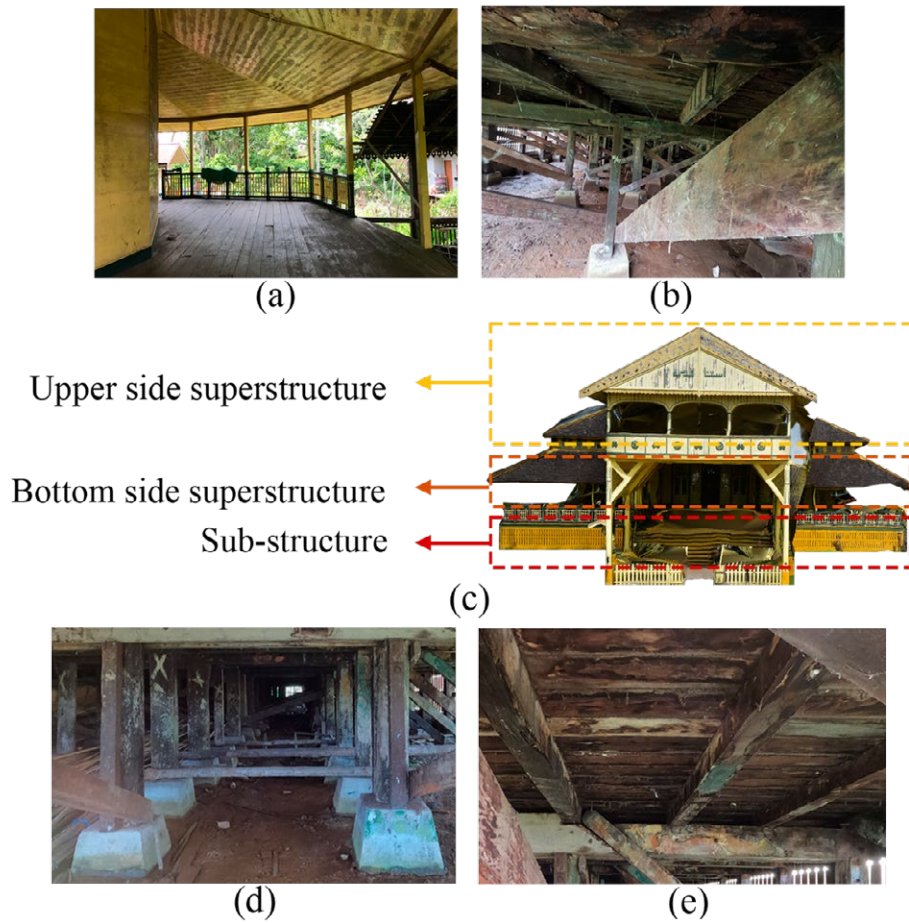


Fig. 3. Physical components of the Kadariah Palace in section C; photo by N. Norita 2021.
 Rys. 3. Fizyczne elementy pałacu Kadariah w sekcji C; fot. N. Norita 2021.



Fig. 4. The condition of non-structural elements of the Kadariah Palace; photo by N. Norita 2021.
 Rys. 4. Stan elementów niekonstrukcyjnych w obrębie pałacu Kadariah; fot. N. Norita 2021.

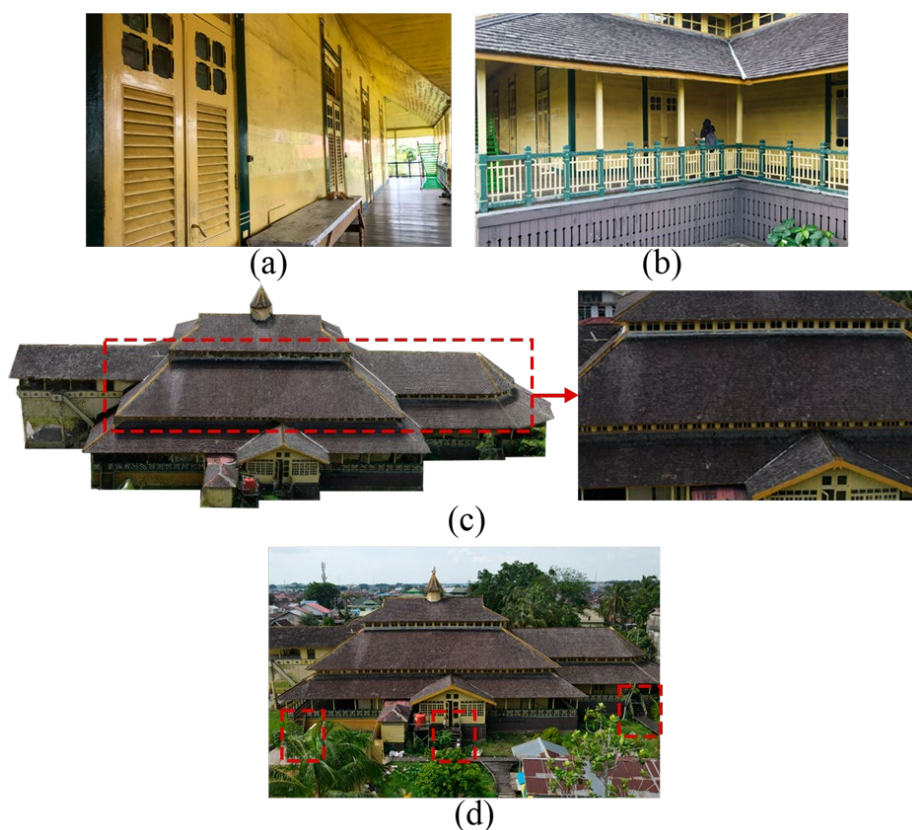


Fig. 5. Aerial Photos of the Kadariah Palace at the section B; photo by N. Norita 2021.
Ryc. 5. Zdjęcia lotnicze pałacu Kadariah na odcinku B; fot. N. Norita 2021.

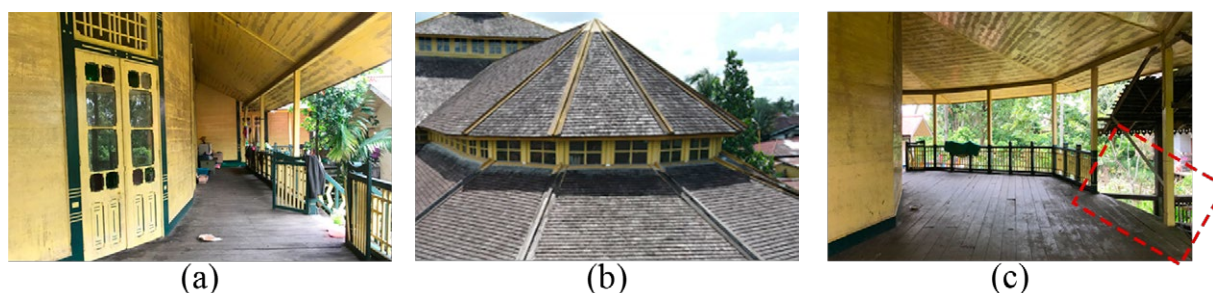


Fig. 6. Situation in the rear section of the Kadariah Palace; photo by N. Norita 2021.
Rys. 6. Sytuacja w tylnej części pałacu Kadariah; fot. N. Norita 2021.

umns with a square shape and one vertical line between a horizontal line (Fig. 7c), column ornaments with one flat line carving (Fig. 7d), column ornaments resembling tree motifs (Fig. 7e), motifs of moon and star symbols on the doors (Fig. 7f), ventilation panels with geometric motifs (Fig. 7g), calligraphy motifs on the screen cliff (Fig. 7h), and floral motifs on the roof plank (Figure 7i). Overall, decorative ornamental elements in all parts of the building are made of belian wood, except for the moon and stars' symbols on the doors, made of iron.

Parts b and c are equipped with the same decorative ornaments, namely ventilation panels with geometric motifs, fence lattices with geometric motifs, and column ornaments with three horizontal lines and four vertical lines at the corners of the column.

Condition of Physical Elements of Kadariah Palace

This 213-year-old building has undergone three significant rehabilitations to date, but some parts of the palace already require renovation—the damage has been caused by various factors, both biological and non-biological.

Biological damage found during field observations was due to fungal factors that were visually apparent. No damage caused by insects was observed with the naked eye. The type of fungus found in the Kadariah Palace building is a white-rot fungus. This fungus affects the concentration of wood lignin, which further fades the wood's original color [Pournou 2020]. The growth of the fungi that cause decay dramatically affects the

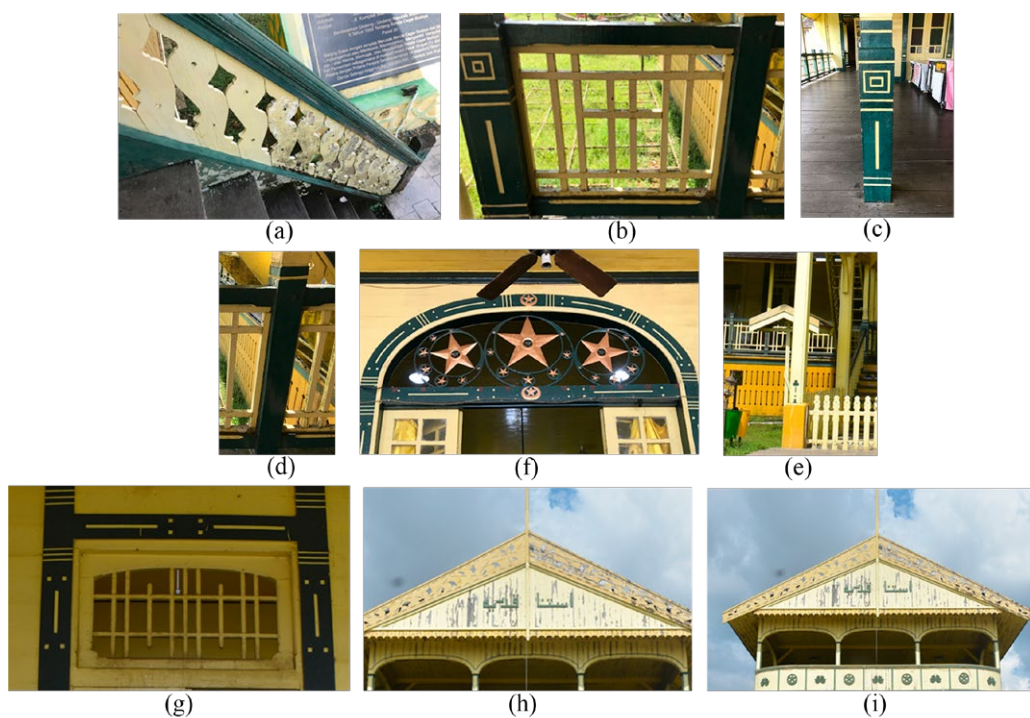


Fig. 7. Decorative ornament elements on the Kadariah Palace; photo by Norita 2021.
Ryc. 7. Dekoracyjne elementy ornamentu na pałacu Kadariah; fot. N. Norita 2021.

structure and stability of the building's strength [Zain and Fajar 2014]. Based on the results of observations and literature studies, the element that has a white layer on top indicates that the component is attacked by white-rot with the effect of bright stains left behind [Shang et al. 2013]. Wood materials of past buildings are usually attacked by wood rot or fungi, resulting in a durability decrease of building materials and structures [Alfieri et al. 2016]. However, besides presenting in the form of stains or spots, white-rot fungi can also be seen in the form of white fibers (Fig. 8c). This type of fungus is quick to attack outdoor construction parts [Irbe et al. 2012], such as foundation elements, floors, and stairs. White spots are visible on the wood surfaces that appear to be in good condition, or parts of the wood that have cracked without changing the external dimensions. In other words, this fungus does not cause cracks on the outer surface of the wood, but only changes the surface color due to the degradation of wood lignin [Riggio et al. 2015].

Damage to the Kadariah Palace was also caused by various non-biological factors, weather factors, and mechanical factors. No non-biological damage was found to the building caused by chemical factors. Weather changes, such as changes in thermal or temperature, wind, rain, dust, pollution, and sunlight have a significant impact on changes in the strength of wood structures [Reinprecht 2016]. The parts of the Kadariah Palace that interact directly with climate and weather changes are the roof covering, stairs, floors, screen spread, and roof planks, as well as several lattice

parts of stairs and columns. Those elements directly contact humidity and air temperature outside the room [Brischke and Thelandersson 2014]. The weathering from rain and ultraviolet radiation very slowly affects only about 2/3 cm per century [Nilsson and Rowell 2012]. A decrease in the strength of the wood structure causes the wood to undergo a rot process and be more easily attacked by fungi and insects [Reinprecht 2016; Singh et al. 2019]. The decay occurs due to the biodegradation of wood cell walls, affecting the density of the wood [Soge et al. 2021]. In addition to being overgrown by microorganisms, the discoloration can occur due to changes in the cellulose layer on the wood [Matsuo et al. 2012] and leave stains on the surface layer of the wood [Brischke and Thelandersson 2014]. Related to the statement of Shupe et al. [2008], current conditions in the Kadariah Palace are the cause of decay since its untreated wood is alternately exposed to wet and dry conditions, such as direct contact with soil, or to conditions where the wood absorbs moisture-- and moisture for a long period. This is because wood that has been exposed to the outdoors for years will experience a change in texture, becoming more and more rotted, thus producing a deformed wood surface [Zabel and Morrell 2020].

Damage due to mechanical factors was found at several points on the walls, columns, and floors of the Kadariah Palace building. Generally, mechanical degradation is caused by wind, sand, dust, cracks, fractures, abrasion, erosion, and compression [Nilsson and Rowell 2012]. One of the causes of mechanical damage to

Element Component		Building Section		
		A	B	C
Structural	Foundation	Attacked by white rot	Attacked by white rot	Attacked by white rot
	Floor	Attacked by white rot	Attacked by white rot	Attacked by white rot
		Damage due to weather factors		Damage due to weather factors
		Damage due to mechanical factors		Damage due to mechanical factors
	Column	Damage due to mechanical factors	Damage due to weather factors	-
Beam	-	-	-	
Non-structural	Door	-	-	-
	Window	-	-	-
	Roof	Damage due to weather factors	Damage due to weather factors	Damage due to weather factors
	Wall	-	Damage due to weather factors	Damage due to mechanical factors
	Stair	Attacked by white rot	Attacked by white rot	-
		Damage due to weather factors	Damage due to weather factors	-
	Screen spread	Damage due to weather factors	-	-
Decorative ornament	Lattice	-	Damage due to weather factors	-
	Symbol	Damage due to weather factors	-	-

Table 1. Conditions of the physical elements of the Kadariah Palace; by Norita 2021
Tabela 1. Warunki fizycznych elementów pałacu Kadariah; opr. N. Norita 2021

the Kadariah Palace is sand. Sand carried by the wind will erode the outer surface of the wood that is not coated with paint [Zabel and Morrell 2020]. Excessive loads applied to the elements are also the cause of mechanical damage so that the wood surface will experience fragmentation or erosion. Cracks are visible in the

wood due to sustained loads, causing a decrease in the vertical load-bearing capacity of timber affected by the reduced cross-sectional area [Dai et al. 2020].

In summary, the factors that cause damage to the physical elements of the Kadariah Palace are biological factors, non-biological factors, weather, and mechanical factors. Those damages can degrade the heritage building character [Satriandika et al. 2019]. Therefore, there are various methods to prevent the degradation. Some coating methods have proven to be effective for wood material. Resin, oil, and wax are good coating agents for belian roof shingles [Morrell et al. 2020]. Another recommended coating agent is paint. The paint fills the pores in the wood and removes the possible space for fungus to grow [Arifin et al. 2022]. The coating can prevent absorption of moisture, several types of fungi, and degradation due to solar radiation. The interesting fact about wooden structures is that they can become stronger and more durable if always soaked by water [Ardianti et al. 2021; Gazali and Fathurrahman 2019; Nurfansyah et al. 2020]. The soil character in Pontianak is wet, as typical of muddy or swampy areas. This condition causes the bottom structure of the Kadariah Palace to be always soaked by water; therefore, the bottom parts are more durable.

In order to effectively stop the assault of dry wood termites in West Kalimantan, liquid chemical protection is frequently utilized as a supplement to structural and hygienic measures [Indriyani et al. 2008; Indriyani et al. 2017]. Future termite control solutions may benefit from using bio-based ingredients to combat subterranean termites made from the crude ethanol extract of *S. Aromaticum* and *M. Leucadendra* [Indriyani et al.

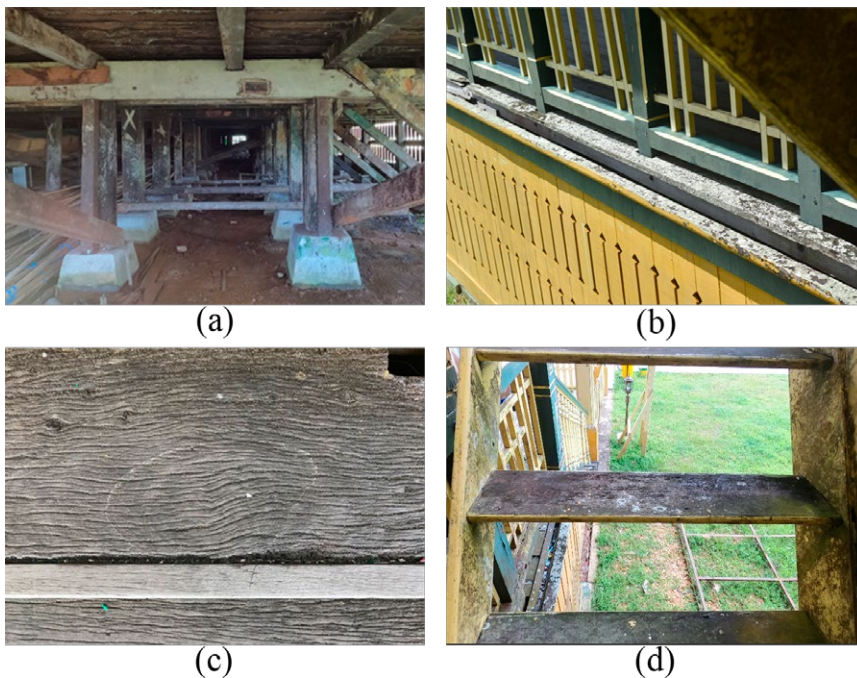


Fig. 8. Biological impact on the wooden surface of structural elements of the Kadariah Palace; by N. Norita 2021.
Rys. 8. Biologiczny wpływ na drewnianą powierzchnię elementów konstrukcyjnych pałacu Kadariah; fot. N. Norita 2021.

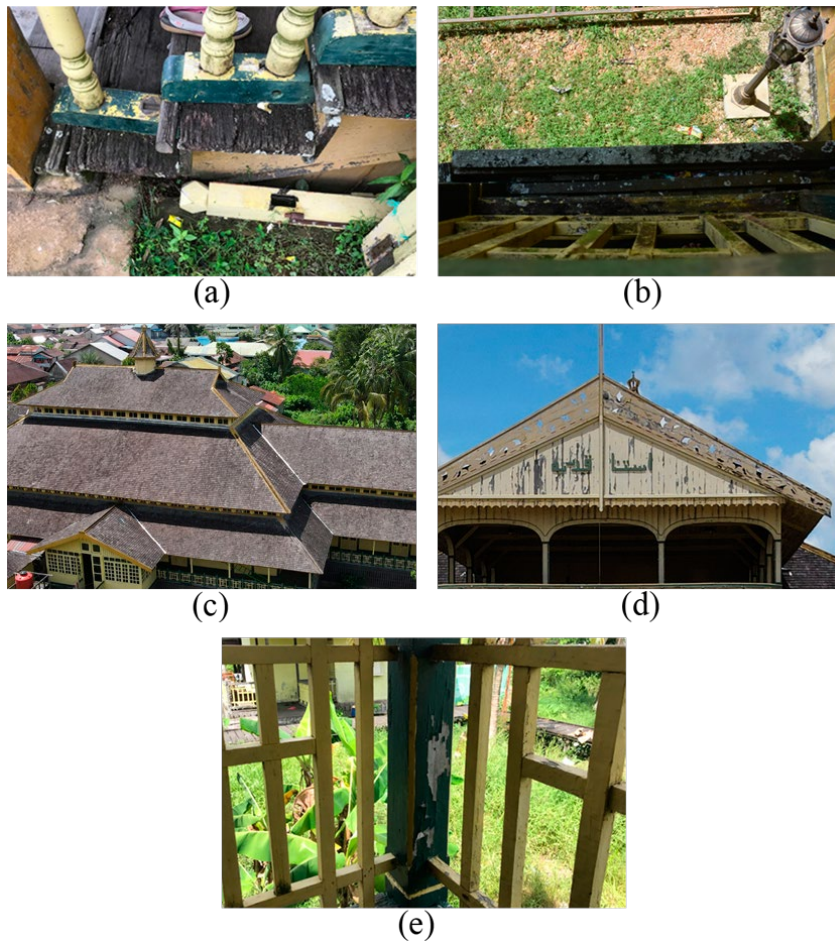


Fig. 9. Effect of weather factors on on physical elements of Kadariah Palace; photo by N. Norita 2021
 Rys. 9. Wpływ czynników atmosferycznych na fizyczne elementy pałacu Kadariah; fot. N. Norita 2021

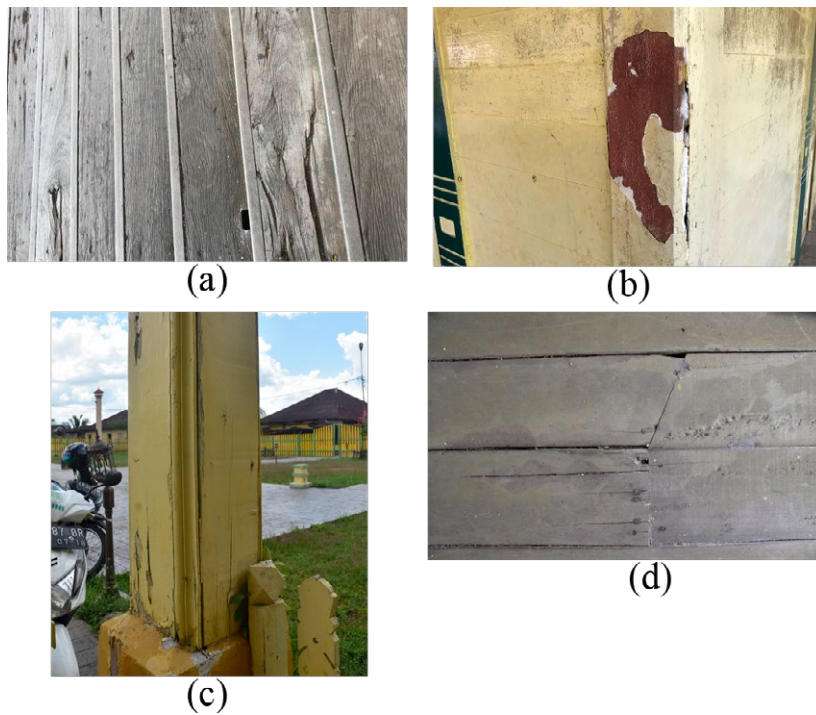


Fig. 10. Effect of mechanical factors on physical elements of Kadariah Palace; photo by N. Norita 2021
 Rys. 10. Wpływ czynników mechanicznych na fizyczne elementy pałacu Kadariah; fot. N. Norita 2021

2016]. To reduce or counteract the effects of weathering brought on by organisms or the environment, the treatment of adding a polychromatic coating to a wooden structure could be applied to wood carvings used as ornamentation on historical West Kalimantan structures [Zain and Putro 2021]. The purpose of this effort is to maintain the value of historical buildings according to the need to preserve and present their aesthetic intentions [Nitto et al. 2016; Tomaszek 2016; Palanti et al. 2014].

Conclusions

The Kadariah Palace was built with physical elements in structural elements, non-structural elements, and decorative ornaments made of belian wood. The structural elements consist of foundations, floors, columns, and beams, whereas non-structural elements consist of doors, windows, roofs, walls, stairs, and screens. The decorative ornamental elements consist of lattices and symbols. The issues of wood rot or fungi affect the physical elements of the Kadariah Palace, causing the

building materials and structures to shrink over time. The Kadariah Palace is built of untreated wood and has been alternately exposed to moist and arid environments, including direct contact with soil or circumstances leading the wood to absorb the moisture and retains it for a lengthy period. Due to the decomposition of wood lignin and the resulting varieties of decay, the physical element exposure has altered the surface color. These elements experience decreased strength due to biological factors from white-rot fungi and non-biological factors from weather, thermal, and mechanical factors. These element's excessive loads cause mechanical damage to the wood surface with fragmentation or erosion. The visible cracks on wood were found, with a decrease in the vertical bearing capacity affected by the reduction in some cross-sectional areas. In this manner, the wood material replaces the color, texture, and causes defects on the surface of the physical elements of the palace building. There are several methods that can be applied to prevent further deterioration, such as applying coating agents and chemical protection against termites.

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Abstract

The use of wood materials as a characteristic of Malay architecture is related to local socio-cultural and environmental factors. The wood type used in traditional Malay structures has endured for hundreds of years, but in a state of decreased strength due to its being continuously exposed to biotic and abiotic harm factors. Documentation of the physical elements and identification of the current condition of the Kadariah Palace could preserve the value of the heritage building for future generations. The data was collected by field observation to be interpreted by applying a qualitative descriptive approach. The construction of the Kadariah Palace with structural, non-structural, and decorative ornaments is indicated by the physical elements of its appearance. The belian wood was used as a building material, which impacted the deterioration of the exteriors by biological and non-biological damage factors. The biological damage factor is caused by white rot, while non-biological damage factors are caused by weather, thermal, and mechanical factors.

Streszczenie

Wykorzystanie materiałów drzewnych jako cechy charakterystycznej architektury malajskiej wiąże się z lokalnymi czynnikami społeczno-kulturowymi i środowiskowymi. Gatunek drewna stosowany w tradycyjnych strukturach malajskich zapewnia setki lat trwałości, ale ma zmniejszoną wytrzymałość przez ciągłe narażenie na biotyczne i abiotyczne czynniki. Dokumentacja elementów fizycznych i identyfikacja obecnego stanu pałacu Kadariah pozwalają zachować wartość zabytkowego budynku dla przyszłych pokoleń. Dane zebrane w trakcie badań terenowych zostały zinterpretowane przez zastosowanie jakościowego podejścia opisowego. Ornamenty konstrukcyjne, niekonstrukcyjne i dekoracyjne składają się na fizyczne elementy wyglądu pałacu. Drewno belian zostało użyte jako materiał budowlany, co wpłynęło na niszczenie elewacji przez czynniki biologiczne i niebiologiczne. Uszkodzenia biologiczne powodowane są białą zgnilizną drewna, natomiast czynniki niebiologiczne to wpływy pogodowe, termiczne i mechaniczne.