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Wood museum biodeterioration of karaeng patingalloang benteng somba opu, Gowa regency

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Abstract. Karaeng Patingalloang Museum plays an important role in the community as a center of history, education, religion, and culture, particularly in South Sulawesi Province, Indonesia. For the continuity of this role, maintenance efforts are needed on the wood of the Museum building. Thus, it can be used for a long time. This research aimed to determine the level of damage caused by wood-damaging organisms in the Museum building, evaluate and document the characteristics or signs of damage that occur in buildings, and identify organisms that attack the building. Destructive organisms observed attacking the Museum's wood were identified based on the signs of the attack found. The results showed that soil termites, dry wood termites, and coloring molds were organisms that attack the wood of the Karaeng Patingalloang Museum building. Damage to the components of this building was classified as a severe attack even though the intensity was less than 0.5% with the occurrence of attacks found on poles, window frames, and walls.

1. Introduction

Cultural Heritage in Law Number 11 Year 2010 is a cultural heritage of material properties in the form of cultural heritage objects, cultural heritage buildings, cultural heritage structures, cultural heritage sites, and cultural heritage areas. The museum is a high-value cultural element. This building needs to be preserved because it has important values for history, science, education, religion, and/or culture through the establishment process. The museum is an inseparable part of the function of the Directorate for the Preservation of Cultural Heritage and Museum to carry out the protection, development, and utilization of cultural heritage. The museum is of has a vital role as a center for communication and information as well as the development of science and education for the wider community. The museum is a place for storing, maintaining, securing, and utilizing material evidence of human culture and nature and the environment to support efforts to protect and preserve the nation's cultural wealth.

Biodeterioration of cultural heritage has become a global problem. Cultural heritage biodeterioration has been intensively studied in recent [1–8] Biodeterioration that occurs is caused by various organisms. In several articles, it is known that various types of fungi were found to have colonized many wooden historical buildings[8,9] Bacteria are also reported in some articles as biodeterioration agents [10]. Apart from these two microorganisms, insects are also documented to cause deterioration, such as termites [1]. Of course, the occurrence of biodeterioration not only causes economic losses but also disrupts the function of the building, the health and comfort of its users.

The museum is a used building as a place for permanent exhibition of objects that deserve public attention, such as historical relics, art, science, and a place to store ancient objects. One of the museums located in South Sulawesi is the Karaeng Pattingalloang Museum located in the Somba Opu Area. Based on information from the UPTD Managing Benteng Somba Opu (2015), this museum was founded in 1992 to complement the Miniature Park in South Sulawesi and was named the Karaeng Pattingalloang Museum, which was taken from the name of one of the scholars of the Kingdom of Gowa. The Karaeng Pattingalloang Museum was built on an area of 600 square meters, which uses the concept of a stilt house. The Karaeng Pattingalloang Museum collection was largely obtained through the excavation of saving the Somba Opu Fortress in 1989, before being revitalized into the South Sulawesi Miniature Park and through procurement. The collections are in the form of: materials (bricks) used in the construction of Somba Opu Fortress, cannon bullets, gun bullets, porcelain fragments, pottery fragments, ceremonial instruments, traditional weapon replicas used in royal ceremonies and four ethnic traditional clothes in South Sulawesi and the West and the collection of ancient currencies that have prevailed in Indonesia.

Karaeng Pattingalloang Museum is an inheritance museum of King Gowa, which was built in 1992, where the building components are dominated by wood-based materials. Thus, this building is also vulnerable to attack by biodeterioration agents such as termites and molds that can inhabit and rot on paintings, textiles, paper, and parts of buildings or materials used for historic art objects. In addition to termites and fungi, various types of beetles can also attack wood, both wood that has long been used and wood that is still new. The results of the survey and initial inspection of the wood components in the museum building showed that there was damage caused by wood-damaging organisms, such as staining and weathering. However, how much damage occurred, the cause of the damage, and what factors are involved in the biodeterioration process are not clearly known. Therefore, this study is intended to determine the level of damage caused by wood-destroying organisms in the Karaeng Pattingalloang museum building, evaluate and document the characteristics or signs of deterioration that occur in buildings, and identify organisms that attack the Karaeng Pattingalloang museum building. This research is useful as an information material in taking steps or maintenance efforts on the wood of museum buildings to last a long time.

2. Materials and methods

2.1. Study Sites

This research was carried out at the Karaeng Pattingalloang Museum, Gowa Regency. The museum building was dominated by wood base material, as shown in figure 1.



Figure 1. Karaeng Pattingalloang Museum Building: (a) front view, (b) side view, (c) inside building

2.2. Damage Evaluation

Wood damage in the Karaeng Pattingalloang Museum building was determined based on the value of the attack intensity and the attack degree. Buildings damage evaluation was begun by data collection

of all types of wood building components in each part of museum buildings such as poles, walls, window sills, floors, doors, and other components. For evaluation of damage to wood components, the steps were: (i) each type of wood component was counted. If the damage was found to the component, then the number of components that were damaged was calculated to determine the attack intensity; (ii) the damage component was also assessed and observed for signs or characteristics of damage caused by each destructive organism; and (iii) documenting the attack characteristics.

2.2.1. Attack intensity (AI). The attack intensity caused by wood destroying organisms was expressed in percent of the wood affected. The intensity of the attack was calculated as a ratio of the amount of wood attacked to the number of wood components in building construction.

2.2.2. Attack Degree (AD). The attack degree was determined by observing each building component of wood visually and assigning values to these components based on the organism's attack criteria as follows: 100 (whole), 75 - 99 (light attack), 50 - 74 (moderate attack), 25 - 49 (massive attack), 0 - 24 (very massive or destroyed attack).

The intensity and degree of the attack obtained were tabulated and analyzed descriptively.

2.3. Collection and Identification of Destroyer Organisms

The organisms that cause damage to wood components were taken, collected, and observed to determine the type.

2.3.1. Mushrooms. Wood components that showed signs of weathering or staining on wood such as white, black, blue, or other pigments were taken to find out the type of fungus that attacked. Intake of fungal hyphae in the component parts attacked by fungi was done by attaching the plaster to the affected part, then the plaster was inserted into a plastic clip and then taken to the laboratory to be isolated and identified its type.

2.3.2. Termites. Components of wood that showed signs of damage such as excrement or coarse grains on the floor around the affected wood components, or other signs of attack such as ground tunnels were removed by the organism (if any). Termites that were found were put into a collection bottle that was filled with 70% ethanol, and the morphology was then observed to determine species identification by referring to the key of determination [11].

2.3.3. Beetles. Wood components that showed signs of damage such as the presence of fine powder in the form of flour on the floor around the components of the wood attacked, or the exit holes taken by the organism. The beetles found were included in 70% ethanol, then morphology was then observed for species determination.

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3. Results and discussion

3.1. Damage Characteristics and Types of Destroyer Organisms

Alike most of the traditional houses of the people of South Sulawesi, locally known as stilts, this museum building was made entirely of wood, including the connection between components using wood instead of nails, known as "pegs" The wooden building components of the Karaeng Pattingalloang Museum observed consisted of poles, windows, doors, stairs, walls, and floors. The top of the building (roof, rafters, and scaffolding) were not observed and measured because they were not permitted by the museum owner, and which includes in detail the components of wood damaged can be seen in table 1.

Table 1. Types and Amounts of Wood Components Karaeng Pattingalloang Museum

Component type	Components Number (pieces)	Damaged Components Number (pieces)	Sort Type	Wood Types Used
Mast	16	0	Block	Ulin
Window	676	3	Board	Ulin
Ladder	50	0	Board	Ulin
Door	401	0	Board	Ulin
Wall	848	1	Board	Ulin
Floor	230	0	Board	Ulin

3.2. Attack by Termite Land

Termites are wood-eating insects (*Termitophagus*) or materials consisting of cellulose [12] and are known as structural pests such as wooden structures, household furniture, books and museum collections [13]. Table 2 depicts that the termite was one of the insects that attack the wood components in the building, namely the window frame and support poles. On a supporting pole, the signs of a termite attack displayed from a single tunnel trail on a wooden surface (Figure 2a). Other signs of attack from these termites were found in window frames on the lower floors of the building in the form of galleries or honeycomb-shaped tunnels (Figure 2b). If we observed at the signs and characteristics of the damage that occurred and when compared with the similarity of the signs and characteristics found in the study of Arif and Nurdianti (2015), it could be suspected that the invading organism was *Coptotermes*, although no organisms were found [14].

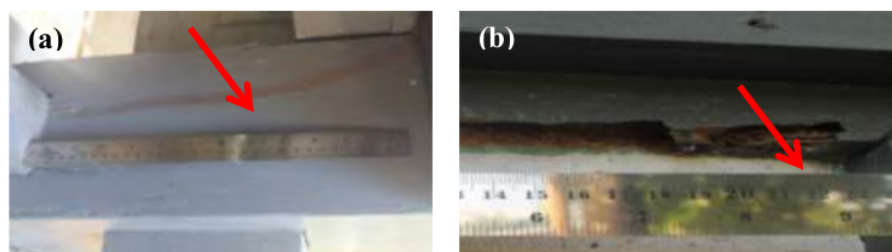


Figure 2. Signs and characteristics of damage caused by soil termites: (a) a single tunnel trail on a pole, and (b) a window frame gallery

Figure 2 proves the traces of a support pole tunnel, even though the soil that was commonly used by termites to make tunnels look cleared. The presence of wandering trails on the surface of objects, such as house buildings [15] and wooden objects [1] demonstrated that the wood component was attacked by subterranean termites. The number of tunnels as traces of an attack can be determined by the type of surface that was passed by termites. Lee's study (2018) presented that suitable surface roughness can positively contribute to browsing speed. Ground termites use this tunnel as a means to reach the object to be attacked [16]. In addition, this tunnel also serves to maintain the environmental humidity needed by termites in carrying out their roaming activities. Soil termites can reach the object of attack even if the object is not directly related to the ground, by building a protective pipe from the ground to the target object through the gaps in the foundation and walls. Soil termites also attack wood by making wood burrows. The form of damage that is often found in wood is attacked by soil termites such as "honey comb" with the characteristic of the presence of soil particles in the burrow [17].

The existence discovery of the termite traces attacked on the wooden components of the museum's pillars and window frames was due to appropriate environmental conditions and allowed the colony to

breed, especially the *Coptotermes* genus. Besides being found attacking in buildings, this type attacked forest plants such as pine trees, *Pinus merkusii*, [18]. In South Sulawesi, this genus is also known to have distributed in most areas, with the dominant occurrence of termite occurrences found in the southern part of South Sulawesi, and vice versa rarely found in the northern part of South Sulawesi. In addition, this species was found to live in the mean temperature range of 32.3°C for a moment and average humidity of a momentary 61.6% [19]. The species of the *Coptotermes* genus has been known and included in 28 species of invasive termites [20]. Several types of termites are known to attack historical buildings in various parts of the world. *Coptotermes gestroi* types were identified as attacking historical buildings in the Phnom Penh National Museum, by entering a typical structural structure using sub-floor cracks in concrete and brickwork. The wood component of Lawang Sewu Heritage Building, Semarang was also found to be attacked by *Coptotermes curvignathus* [21].

3.3. Dry Wood Termite Attack

Besides the [1] termites, building components from the Karaeng Pattingalloang Museum were also attacked by dry wood termites. Dry wood termites are a group of termites from the Kalotermitidae family, which live in a place that is not related to the soil and lives throughout its life in its food source. This termite is a pest of dry structural sawn wood and wood furniture [22]. In this study, parts of the building that were attacked by termites were window frames and window boards. Damage to the window frame on the upper floor (2nd floor) due to dry-wood termite attack was indicated damage to the wood parts and the presence of coarse brown granules on the floor coming from the underside of the damaged wood. In addition, the laronic wings were also observed around the affected wood and on the surface of the affected wood leaving a layer of wood thick as veneer. The damage sign presents in Figure 3.

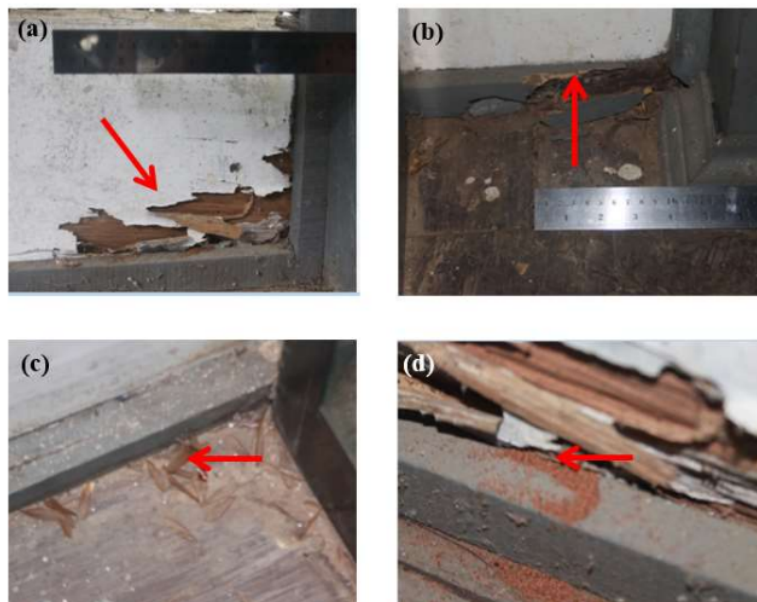


Figure 3. Signs and damage characteristics caused by dry wood termites: (a) very thin remaining wood surface layers, (b) loss of wood surface, (c) moths wings, and (d) coarse brown granules.

Although no termite specimens were found at the time of the research, the damage to the window frames on the upper floors of the building was thought to be caused by termites *Cryptotermes cynocephalus* through the signs and characteristics of the damage caused. This is according to what

was stated by Nandika et al. (2003) that attack marks such as wood become porous, there is a thin layer of wood left on the surface of the wood, the presence of small brownish excrement items that often fall on the floor or around attacked wood is a sign of attack from dry wood termites (*Cryptotermes cynocephalus*) [23].

3.4. Dye Fungus Attack

Fungus is an important biodeterioration agent and can easily be found to colonize material in cultural heritage [24]. In the Karaeng Pattingalloang Museum building, the presence of these microorganisms was presented on the walls and was recognized as a coloring fungus. This fungus usually attacks material, especially the surface of a lignocellulose material, which is moist. Colonization of this dye fungus was indicated by the presence of black spots found (Figure 4).

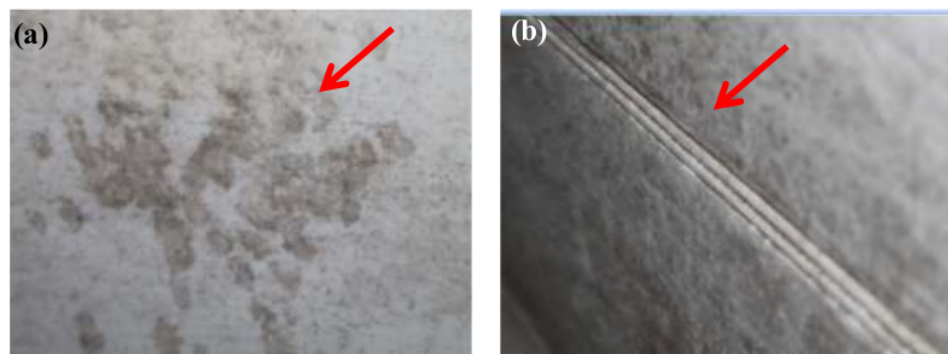


Figure 4. Characteristics of coloring fungus attacks: (a) spots or stains on the wall surface, and (b) the appearance of coloring on the wood surface.

The identification results of fungal specimens taken on the walls of the affected building (Figure 4a) indicated that the attack was caused by coloring fungi, which belonged to the *Aspergillus niger* species. The characteristics of *Aspergillus niger* which has a large conidial head, round and black, brown or black brown [25]. This fungus grows quickly using nutrients around it. *Aspergillus niger* is one of the most common and easily identified species of the *Aspergillus* genus. This fungus grows optimally in the temperature range between 24 and 37°C, water activity >0.95, and pH levels between 4 and 6.5 [26].

Aspergillus is one of eight genera (*Chaetomium*, *Cladosporium*, *Fusarium*, *Penicillium*, *Stenohyllum*, *Talaromyces*, and *Trichoderma*) which were also successfully isolated from wood and soil in ancient wood from the Middle Cemetery at Abydos, Egypt [1]. Another research from Carlo et al. (2016) related to the presence of fungi and bacteria in the interior of the Cultural Heritage environment and the relationship of risks to human health found several genera (*Aspergillus*, *Alternaria*, *Penicillium*, and *Aureobasidium*) that were most commonly grown and isolated from the library / archive and museum environment [10]. These microorganisms affect human health, especially building occupants. Some *Aspergillus* species are known to be pathogenic to humans and animals, especially *A. niger*, which is most commonly associated with tract infections respiratory.

Fungal attacks that can be isolated from wood components of historic buildings are not only limited to coloring fungi, but also white and brown weathering fungi as reported by [24] and discovered by Riggio et al. (2013) through integrated sensing and modeling techniques from degraded wood surfaces of historic buildings [5]. Even the research from Ortiz et al. (2014) on the historic wooden churches of Chilo, Chile found 29 Basidiomycota and 18 Ascomycota based on rDNA sequences analysis [8].

3.5. Level of Building Damage

The research results showed that the Karaeng Pattingalloang Museum was damaged due to attacks by wood destroying organisms such as termites and fungi. The wood components attacked by wood-destroying organisms were found in wall and window components. Data on the building components that were attacked, the type of wood used, the intensity of the attack, the degree of attack, and the type of attacking organism are presented and summarized in table 3.

Table 2. Level of attack on wood destroying organisms in each building component.

The attack component	Level Attack		Types of wood-destroying organisms
	Attack Intensity (%)	Attack Degree	
Pole	0	100	None
Window	0,44	25-49	Soil termites and dry wood termites
Door	0	100	None
Stair	0	100	None
Wall	0,23	75-99	Mushroom Coloring
Floor	0	100	None

Table 3 described that the attack intensity was less than 0.5%, which indicated that the attack intensity of wood-destroying organisms on wood components in the building was relatively rare, although based on observations the attack degree was classified as severe. Even the doors, stairs and floor were not found any attack or the intensity value was equal to 0%, which meant that all the components making up the part were still intact. The building component that experiences the highest intensity of attack was in the window section; although only three components out of a total of 676 window-forming components were found to be damaged. The damage experienced to the window components on the lower floor was caused by ground termites, while the damage to the window components on the upper floor was caused by dry wood termites. Judging from its construction position, the window components on the lower floor and supporting poles of the building were more vulnerable to being attacked by termites because they were located closer to the ground surface. This was consistent with what was stated by Siregar et al (2007) that the door frame and window sill on a house whose height is not so far from the ground, will make it easier for termites to ascend to the building components. The amount of building damage caused by soil termite attacks (especially *C. gestroi*) as proposed by Megna and Liotta (2015) can be severe in a relatively short time, especially if the structure is attacked by soil termites that have a large number of adult colonies [27].

If soil termites were found to attack building components that were close to the ground surface as a source of moisture; instead dry wood termites were found to attack window components that were located some distance from the ground surface, namely the window frame on the upper floor. As the name implies, dry wood termites can live on woods that have low water content in building houses, buildings, or other buildings. The wood that was attacked becomes porous and causes irregular cavities in the wood. There was a thin layer left on the surface of the wood so that the attack was less visible from the outside, but with just a little pressure the wood would be damaged. The visible sign of attack was the excretion of a small grains of 0.6 - 0.88 mm in diameter, brownish in color released from a large attack hole [28]. The results of this research were also in line with the research of Indrayani et al. (2004), which found 83.3% of dry wood termite attacks occurred in wooden buildings over 5 years old. The relationship between environmental conditions and the presence of wood-destroying organisms is also stated by Tambunan and Nandika (1989) as a very close relationship, both of which influence each other.

Besides the termites, coloring fungi from the mold group were also found to attack the walls with 0.23% intensity, of which only two components out of a total of 848 components were damaged. The presence of coloring fungi in one of the components of the museum was caused by the existence of supporting environmental factors, namely humidity and temperature, where the temperature and

humidity found in the field are 32°C and 64%. Basically, most molds like environments with temperatures between 15 °C and 30°C, although there are also species that grow below and above that temperature [29]. The presence of mold in buildings leads to Sick Building Syndrome such as health problems and damage to building materials, books, clothing, and stored food; whose growth is influenced by humidity, nutrition, light, oxygen, and temperature [30]. In addition, in this study the incidence of an attack by a coloring fungus was found on the left side of the building, where in the building part it received shade from a large mango tree (*Mangifera indica*), so it did not get direct sunlight, as seen in Figure 5d.



Figure 5. Building surrounding conditions: (a) front, (b) rear, (c) right side, and (d) left side

Figure 5 displays that environmental factors also play a role in causing the wood damage in the Karaeng Pattingalloang museum component. This is supported by the statement of Muin (2012) that environmental conditions such as the level of temperature, light, and humidity accelerate the damage to building wood, which impact to the used-age of wood to be shorter.

4. Conclusions

Referring to the results and discussion, it can be concluded as follows: damage to the building components of the Karaeng Pattingalloang Museum was classified as a severe attack even though the intensity value was less than 0.5%, with attacks occurring on window frames and walls. Destructive organisms found in the Karaeng Pattingalloang Museum building based on an evaluation of the signs and characteristics of the damage were soil termites (*Coptotermes*), dry wood termites (*Cryptotermes cynosephalus*) and coloring fungus (*Aspergillus niger*). Further attention is needed for the protection of buildings due to the presence of affected building components.

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