Global-COE Program

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Title: Investigation of Biodeterioration in Indonesian Wooden Structures

Place of survey: Yogyakarta (Indonesia)

Member: Takuro Mori (Assistant Professor, Research Institute for Sustainable Humanosphere, Kyoto University)

Yoshiyuki Yanase (Assistant Professor, Graduate School of Agriculture, Kyoto University)

Sulaeman Yusuf (LIPI Urban Pest Management)

1 Introduction

At present, there are few wooden houses or buildings in Indonesia, although wood beams are often used in the building materials. In contrast, many traditional wooden *joglo* buildings exist in the city of Yogyakarta. Joglo-style building is the traditional Javanese wooden post and beam construction style. Joglo buildings use teak wood (*Tectona grandis*) as the primary construction material of the structural beams, sub-beams, and ornaments. These buildings employ a mortise and tenon construction technique. Joglo were originally constructed for members of the upper class, e.g., sultans' palaces (Figure 1). The roof utilizes complex and sophisticated construction techniques. As such, it is assumed that they will have sustained damage as a result of fungi caused by leaks in some areas. It is also assumed that attacks by termites will be common because of the exposed wooden beams.

In this study, an investigation of the posts of a sultan's palace joglo and the posts of a house-style joglo that includes guest houses and main buildings in the area of Kotagete were carried out in order to examine the biodeterioration.

Figure 1. Sultan's palace joglo at Srimanganti Hall

Figure 2. Joglo guest house and main building

2 Measurements

Moisture content and ultrasonic velocity were measured on the surface of the teak posts at approximately 300, 1000, and 2000 mm from the ground. A wood moisture tester (HM-530, Kett Electric Laboratory) was utilized to measure the moisture content of teak wood; the specific gravity was set to 0.65. The propagation time of an ultrasonic wave in the teak post was measured using an ultrasonic sound timer (Dr. Wood, Akita SKK Inc.) with an ultrasonic transmitter and receiver. The transmitter and receiver were attached to the surface of the teak post and the propagation time of the ultrasonic wave between the transmitter and the receiver was measured. Ultrasonic velocity was calculated from the propagation time and the distance between the transmitter and the receiver, namely, the width of the teak post. Acoustic emission (AE) generated by termite feeding activity in the wood was also detected using AE measurement apparatus on the teak post. The measurement results of moisture content and ultrasonic velocity are presented in Figure 3.

Figure 3. Measurement of moisture content and ultrasonic velocity

3 Results and Discussion

The results of two investigations, that for a palace building and that for a house-style building, will be discussed herein.

First, an example from the building data of the five palaces is presented. Figure 1 depicts the building. It is used for sultans to welcome the arrival of important guests. It was built approximately 170 years ago. Table 1 presents the results of moisture content and ultrasonic velocity. The post location is illustrated in Figure 4.

Visual investigation revealed that the post had been attacked by fungi and drywood termites. The moisture content indicated that the bottom had more moisture than the top. Some posts had a moisture content that exceeded 28%. These parts are considered to be at high risk of deterioration as a result of fungi. The ultrasonic velocity was measured to be between 1500 and 2100 m/s. The relationship between moisture content and ultrasonic velocity was poor. Some parts were measured to be approximately 1000 m/s or less, and, as such, it was assumed that they had been damaged by fungi and/or drywood termites. Low ultrasonic velocity values were only obtained at the bottom of the posts.

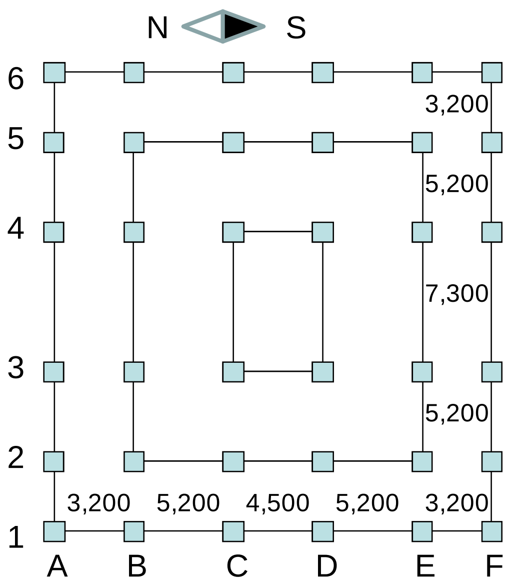

Figure 4. Post location of Srimanganti Hall (unit: mm)

Table 1. Results of moisture content and ultrasonic velocity of Srimanganti Hall

Post	Moisture content (%)			Ultrasonic velocity (m/s)		
	Bottom	Middle	Top	Bottom	Middle	Top
A-1	13.0	10.5	13.5	1827	1663	1730
A-2	14.0	11.5	14.0	1496	1651	1800
A-3	11.5	11.0	12.5	1642	1832	1850
A-4	14.0	13.0	15.0	1710	1615	1721
A-5	12.5	11.5	12.0	1851	1923	1851
A-6	15.0	11.0	11.0	1785	1934	1869
B-1	18.0	12.5	11.5	1057	1693	1534
B-2	23.0	15.5	12.5	1517	1510	1556
B-3	17.0	13.0	12.5	1764	2012	1877
B-4	12.0	10.0	10.5	1467	1790	1955
B-5	16.5	12.5	14.5	2129	1658	1864
B-6	14.5	17.0	14.5	1534	2143	1742
C-1	15.5	9.5	15.0	1812	1812	1895
C-2	15.5	13.0	14.0	1735	1744	1503
C-3	28.5	25.5	29.0	1447	1766	1801
C-4	29.5	25.0	23.5	1693	1721	1946
C-5	12.5	11.0	9.5	1462	1583	1680
C-6	12.0	13.0	10.5	1595	1673	1663
D-1	14.0	12.5	9.5	1843	2022	1818
D-2	14.5	11.5	11.0	2050	2000	1735
D-3	31.0	25.0	25.5	1435	1771	1761
D-4	33.5	30.5	30.5	1740	1826	1826
D-5	11.0	13.0	14.0	1538	1880	1919
D-6	15.5	12.5	12.0	1958	1918	1818
E-1	14.5	12.0	12.5	1178	1982	1667
E-2	17.0	12.5	11.5	1667	2006	1803
E-3	12.5	10.5	10.5	1875	1583	1746
E-4	12.0	12.5	14.0	1759	2003	1824
E-5	14.0	11.0	12.0	786	1624	1531
E-6	15.5	11.5	12.0	1811	1858	1986
F-1	15.5	11.5	12.5	918	1904	1989
F-2	13.5	12.5	12.0	1736	1782	1765
F-3	13.5	13.5	12.5	1811	1857	1798
F-4	20.5	16.5	17.0	1702	2004	2056
F-5	14.5	12.5	12.0	1875	2038	2000
F-6	12.0	12.0	10.5	1408	2190	1834

For the house-style buildings, damage to the teak posts caused by drywood termites or fungi was observed by visual inspection of the four guest houses and two main buildings. All visible posts in the six joglo buildings were investigated by measuring the moisture content and ultrasonic velocity. Figure 5 depicts an example of one of the sixteen posts in one of these joglo buildings constructed approximately 200 years ago.

The moisture content and ultrasonic velocity of the sixteen posts in the guest house are presented in Table 2. The highest moisture content was measured at the bottom position 300 mm from the floor; the moisture content decreased in the upper part. Damage to the teak post caused by drywood termites was observed on all parts of the post, regardless of the moisture content, and the damage caused by fungi was minimal in this guest house. The bottom part of the post, which has higher moisture content, may be strongly attacked by termites if an infestation of subterranean termites occurred.

No significant relationships between moisture content and ultrasonic velocity were obtained in the measurement of the six joglo buildings.

The ultrasonic velocities were mostly between 1,500 and 2,000 m/s. The ultrasonic velocity where intense damage caused by drywood termites was observed was less than 1,500 m/s whereas that of a sound post was approximately 2,000 m/s. This indicates that areas where the ultrasonic velocity was near 1,500 m/s may be attacked by drywood termites; there were many holes or galleries in the post though damage was not observed by visual inspection.

No significant AE values were detected in any of the visible posts in the six joglo buildings.

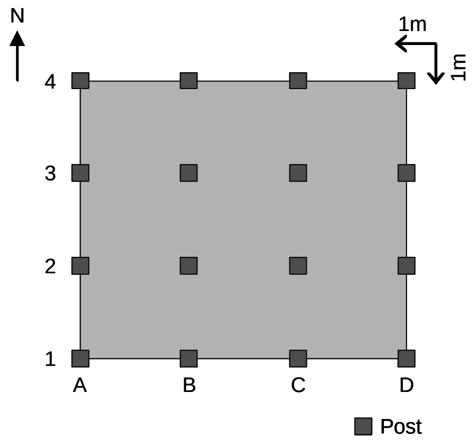

Figure 5. Location of teak posts in the joglo-style guest house

Table 2. Moisture content and ultrasonic velocity of teak posts in the joglo-style guest house

Post	Moisture content (%)			Ultrasonic velocity (m/s)		
	Bottom	Middle	Top	Bottom	Middle	Top
A-1	21.0	12.5	12.0	1500	1358	1440
A-2	20.5	12.5	7.0	1812	1850	1859
A-3	25.0	10.5	6.5	1761	1587	1595
A-4	15.0	11.0	10.5	1552	1572	1446
B-1	-	15.5	13.5	1765	1739	1827
B-2	19.0	8.5	11.5	1601	2004	1963
B-3	18.0	10.5	9.5	2000	1841	1780
B-4	16.5	9.5	9.0	1821	1664	1694
C-1	-	12.5	10.0	1603	1950	1581
C-2	14.5	9.5	10.0	1684	1905	1905
C-3	22.0	12.5	15.5	1818	1839	1818
C-4	19.0	12.0	13.5	1595	1603	1546
D-1	16.5	11.0	11.0	1943	1875	1705
D-2	28.5	13.0	13.5	1779	1833	1681
D-3	24.5	10.0	10.5	1614	1818	1690
D-4	17.5	13.0	11.5	2033	1842	1888

4 Conclusion

The biodeterioration of teak wood used in traditional Indonesian joglo wooden structures was investigated through an evaluation of the ultrasonic velocity, moisture content, acoustic emission, and so on. Damage caused by drywood termites or fungi was found in the joglo buildings of the sultan’s palace and in the area of Kotagete. No significant relationships between moisture content and ultrasonic velocity were obtained in the measurement of joglo buildings, and no drywood termites were detected or collected in this survey.

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