**Service life prediction of historic timber-framed structures of the kadariah palace in Pontianak, Indonesia**

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**Abstract.** Durability is a significant issue when using timber in construction, especially for the historic building aged hundreds of years. The heritage building should be well preserved as a national identity and also as a legacy of humanity. Thus, it is crucial to know the remaining service life of the building. It can be used to decide the time when the repair or replacement has to be done. The decay depth calculation shows that the main structural elements will reach the center of the cross-section (75 mm) in 150 years (around the year 1920). The condition threatens the stability and safety of the building. The additional width and thickness to the existing structural elements cross-section and the application of weather shield paint on the surface of structural elements periodically in recent times proved to be effective in maintaining the building remain to stand.

**Keywords:** service life, timber structures, historic building, kadariah palace

1. **Introduction**

The existing historic building is essential to be well preserved as a national identity and a legacy of humanity. Indonesia, a country rich with cultural heritage, has numerous historic timber buildings. The most ordinary types of these buildings are Sultanate’s Palaces and Old Mosques. One of the buildings still function is Kadariah Palace. It is a Sultanate Palace established in 1771 by Syarif Abdurrahman Al-Qadri, the first Sultan of Pontianak Sultanate. The Sultanate was located at the Kapuas River's mouth in today’s Indonesian province of West Kalimantan.

Durability is still an issue when using timber in construction. Furthermore, the historic buildings aged hundreds of years usually suffer from several types of degradation mechanisms. This condition indeed threatens the service life of the building. Therefore, it is essential to know the existing building's remaining service life to determine the necessity of repair or replacement. There are much research has been done to model the service life of timber structures. Van de Kuilen [1] combined the durability models with strength models, Viitanen et al. [2] presented an empirical model for wood decay development which can be incorporated into a hygrothermal model of building physics, and Nofal and Kumaran [3] linked a durability assessment system with a model for structural and hygrothermal analysis with damage functions. Zelinka et al. [4] presented a combined heat, moisture, and corrosion model to simulate the corrosion of metal fasteners embedded in solid wood exposed to the exterior environment and Saito et al. [5] integrated hygrothermal analysis with the decaying process of wood structures caused by moisture accumulation. Wang et al. [6] and MacKenzie et al. [7] presented an extensive and long time field and laboratory research and experience in the durability of timber in Australia. Besides, Bornemann et al. [8] applied data-sets to a dose-response performance model considering wood MC and temperature. Kutnik et al. [9] showed standardization work in wood durability and preservation at the European level, and Meyer-Veltrup et al. [10] presented the factorization approach based on the dose-response correlation between wood material climate and responding fungal decay. Prabowo and Hilmy [11] inserted Indonesian climate parameters into CSIRO decay model.

The research on the durability of timber structures in the Indonesian tropical environment is still minimal. Thus, it is decided to adopt one of the internationally notable models in this research. It is a timber durability model developed in [7]. This model is chosen considering the geographical proximity of Australia to Indonesia. This geographical issue is assumed to influence several parameters involved in the model, among other temperatures, moisture, degradation mechanisms, and wood species. Parameters such as durability class and Indonesian timber species will be incorporated to address Indonesian tropical climate issues.

1. **Methodology**

The predicted decay model is taken as a basis of service life prediction of the Kadariah Palace. This model is adopted from the Australian CSIRO (Commonwealth Scientific and Industrial Research Organisation). The model in this paper considers the condition for decay above ground. The macro-climate of Pontianak's city will be reported, and the field hygro-thermal measurements will be carried out. The data regarding the Kadariah Palace’s main structural elements will also be addressed.

*2.1. Predicted Decay Model*

The predicted decay model consists of two parts. The first part is related to the value of decay depth and right at the initiation of decay. The second part deals with the amount of decay depth for the time after the start of deterioration. This model has two main parameters: a decay lag (tlag) expressed in years and a decay rate (r) expressed in mm/year. The component of the mathematical equation of the model can be written in the form of equation (1) until equation (5).

  (1)

  (2)

  (3)

  (4)

  (5)

where d(t) = decay depth after t years of installation, d(0) = decay depth at the initiation time, kwood = wood parameter, kclimate = climate parameter, kt = thickness parameter, kw = width parameter, kn = fastener parameter, dan kg = geometry parameter. The model can be depicted in figure 1.

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|  | **Figure 1.** Decay model, d(t) vs. t. [6] |

*2.2. Macro-climate of the city of Pontianak*

The macro-climate data presented here are relative humidity and temperature. These two data are based on the climate data recorded by BMKG (Meteorological, Climatological, and Geophysical Agency) in Supadio International Airport (IATA: PNK, ICAO: WIOO), West Kalimantan, Indonesia. The data obtained from July 2004 until July 2019 [12]. The data plotted, as shown in figure 2 and figure 3.

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| **Figure 2.** Relative Humidity in July (2004-2019). |  | **Figure 3.** The temperature in July (2004-2019). |

*2.3. The Kadariah Palace’s main structural elements*

The studied building's main structural elements are made of Belian (ulin) (Botanical name: *Eusideroxylon zwageri*). This Indonesian local wood species is famous for its durability against the weather. It is classified in durability and strength class 1. The main structural frame of the building consists of a column and beam system and floor system. The cross-section is rectangular with dimensions 15 cm x 15 cm. The columns can be divided into the primary main supporting column and the secondary supporting column. The building plan, building section, and front view of the Kadariah Palace can be seen in figure 6.

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|  | **Figure 4.** Building plan, building section, and front view. |

*2.4. The hygro-thermal measurements of the building*

The measurements are conducted using the humidity – digital temperature instrument (YK-2001TM type, Lutron, Taiwan), Figure 5. It is done according to ASTM F2420-05 [13]. The temperature (T) and relative humidity (RH) measurements were carried out for exterior and interior columns. The measurements were conducted three separate times, in the morning (from 8 am until 10 am), noon (from 11.30 am to 1.30 pm), and in the afternoon (from 4 pm to 6 pm). It is done in July 2020. The results can be seen in figure 5 until figure 8.

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| **Figure 5.** T (exterior columns) |  | **Figure 6.** T (interior columns) |

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| **Figure 7.** RH (exterior columns) |  | **Figure 8.** RH (interior columns) |

1. **Results and Discussions**

The calculation of predicted service life of Kadariah Palace has been done for the main structural elements. The decay depth is assumed to take place at the first time at 5 mm deep below the surface of the timber structural elements. The input parameters for the model among others: kwood = 0.5 (ulin species), kclimate = 0.4 (the most hazardous zone), kp = 3.5 (ulin, painted timber), kt = 1 (thickness 150 mm), kw = 1,3 (width 150 mm), kn = 1 (no connector), kg1 = 0.3 (non-contact), kg2 = 2.

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| **Figure 9.** d(t) during the building life |  | **Figure 10.** d(t) at the time of tlag |

Figure 9 plotted the decay depth, d(t) versus the time variable (t) during the building’s whole service life. The resulted graph show a decay rate (r) = 0.56 mm/year and decay lag (tlag) = 13.914 years. The first part of the graph demonstrates a parabolic curve according to the formula dt=ct2. Meanwhile, the second part of the graph gives a linear curve based on the formula (t-tlag)r. Figure 10 illustrated the decay depth, d(t) versus the time variable for 50 years period. It is plotted to simulate the occurrence of tlag more clearly. It is interesting to notice that the decay rate will reach the center of the cross-section elements in 150 years.

1. **Conclusion**

It is quite demanding some more practical and straightforward formulation of historic timber buildings' service life in Indonesia. It is required to determine the time when the repair or replacement has to be done. The numerical simulation of the decay depth for Kadariah Palace shows that the main structural elements will reach the cross-section center in 150 years (around the year 1920). This condition indeed threatens the stability and the safety of the building. The fact that the building remains to stand nowadays is due to the additional width and thickness of the existing structural elements cross-section. The other reason is due to the application of weather shield paint on the surface of structural elements periodically in recent times.

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1. **References**

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| [1] | van de Kuilen JW. Service life modelling of timber structures. Materials and Structures. 2007; 40. |
| [2] | Viitanen H, Toratti T, Makkonen L, Peuhkuri R, Ojanen T, Ruokolainen L, et al. Towards modeling of decay risk of wooden materials. European Journal of Wood and Wood Products. 2010; 68. |
| [3] | Nofal M, Kumaran K. Biological damage function models for durability assessments of wood and wood-based products in building envelopes. European Journal of Wood and Wood Products. 2011; 69. |
| [4] | Zelinka SL, Derome D, Glass SV. Combining hygrothermal and corrosion models to predict corrosion of metal fasteners embedded in wood. Building and Environment. 2011; 46. |
| [5] | Saito H, Fukuda K, Sawachi T. Integration model of hygrothermal analysis with decay process for durability assessment of building envelopes. Building Simulation. 2012; 5. |
| [6] | Wang CH, Leicester RH, Nguyen MN. Manual 4 – Decay above- ground. Victoria: Forest and Wood Products Australia Limited (CSIRO Sustainable Ecosystems); 2008. |
| [7] | MacKenzie C, Wang CH, Leicester RH, Foliente GC, Nguyen MN. Timber service life design - Design guide for durability (Revised Version). Victoria: Forest and Wood Products Australia Limited; 2013. |
| [8] | Bornemann T, Brischke C, Alfredsen G. Decay of wooden commodities – moisture risk analysis, service life prediction and performance assessments in the field. Wood Material Science and Engineering. 2014; 9. |
| [9] | Kutnik M, Suttie E, Brischke C. European standards on durability and performance of wood and wood-based products – Trends and challenges. Wood Material Science and Engineering. 2014; 9. |
| [10] | Meyer-Veltrup L, Brischke C, Niklewski J, Hansson EF. Design and performance prediction of timber bridges based on a factorization approach. Wood material science & engineering. 2018; 13. |
| [11] | Prabowo H, Hilmy M. An overview of durability model for timber structure decay under Indonesian climate. In IOP Conf. Series: Earth and Environmental Science; 2019: IOP Publishing. |
| [12] | BPS. Provinsi Kalimantan Barat dalam Angka 2020. Pontianak: Badan Pusat Statistik. |
| [13] | ASTM. ASTM F2170 - 16b Standard Test Method for Determining Relative Humidity Using in situ Probes. West Conshohocken, PA:; 2016. |

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