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FORENSIC ANALYSIS OF CULTURAL HERITAGE BUILDING MAINTENANCE

文化遺產建築維護的法醫學分析

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Abstract

Older buildings, including those designated as cultural heritage sites, are extremely susceptible to damage. The severity of these potential problems can be determined after conducting a thorough identification of the site. Many different factors can cause damage to these structures. Maintenance of cultural heritage buildings must be done through routine or periodic examinations to determine the condition of the building. This study aims to estimate the condition and value of reconstruction of the Immanuel Church as a cultural heritage building, as well as determine the causes and effects of the damage. Building reliability is measured using scoring and weight systems, based on Building Research Establishment Digest 268 of 1988. The result of this examination of the church building's construction components shows a decrease in quality. The highest quality reduction was found on the roof coverings (24.3%), followed by the flat roof and chamfer (20.4%), then the structural construction system (19.0%). Based on these examination results, we determined that the reliability value of Gereja Blenduk Semarang Church Building was 70.9%, assuming moderate maintenance conditions.

Keywords: Cultural Heritage, Buildings Maintenance, Construction Component, Buildings Reliability, Buildings Pathology

摘要 包括被指定為文化遺產的建築在內的舊建築極易受到損壞。這些潛在問題的嚴重性可以在對站點進行徹底識別之後確定。許多不同的因素可能會損壞這些結構。必須通過例行或定期檢查來確定文化遺產建築物的狀況，對文化遺產建築物進行維護。這項研究旨在評估伊曼紐爾教堂作為文化遺產建築的重建條件和價值，並確定破壞的原因和影響。根據 1988 年的建築研究機構摘要 268，使用計分和權重系統對建築物的可靠性進行測量。對教堂建築結構部件的檢查結果表明質量下降。屋頂覆蓋物的質量下降最高（24.3％），其次是平屋頂和倒角（20.4％），其次是結構施工系統（19.0％）。根據這些檢查結果，假設維護條件適中，我們確定 Blenduk 教堂三寶壟教堂的

可靠性值為 70.9%

关键词: 文化遺產，建築物維護，建築構件，建築物可靠性，建築物病理學

I. INTRODUCTION

Some older buildings in Jakarta (the capital city of Indonesia) have been determined as cultural heritage buildings. The regulations state that a cultural heritage building is a that must be environmentally protected. This designation is determined based on the criteria of historical value, age, authenticity, scarcity, landmark, and architectural values [1], [2]. Buildings with those criteria are protected due to its essential value to history, science, culture, education, etc. This study is a case study of the Gereja Blenduk Semarang (GPIB Immanuel) Church, one of the Dutch cultural heritage buildings on Medan Merdeka Timur Street No.10, Central Jakarta; it is a landmark of Jakarta. The buildings are in the Palladian style, an 18th-century classic architectural style. The church has a symmetrical axis with a circular worship hall in the center [3]. Because of this, the church is also known as the Round Church [4], [5].

As a cultural heritage building, regular monitoring and evaluation are very important. The building's damage evaluation must be conducted as early as possible so that it will not cause any adverse impact on its physical structure [6], [7], [8]. The study of the identification of cultural heritage buildings is regulated by the Minister of Public Works and Housing Regulation No. 01/PRT/M/2015, Preserved Cultural Heritage Buildings. This study is a preliminary study to identify physical conditions in terms of architecture, structure, and utility, as well as the historical and archaeological values of the cultural heritage buildings [9], [10]. The guidelines regarding the management of building maintenance are written in the Minister of Public Works Regulation No. 45/PRT/M/2007 [11].

Building pathology is defined as systematic knowledge of a building's "diseases", to know the cause, symptoms, and remedial treatment of such issues. Building pathology requires a holistic approach to the building's anatomical conditions, such as building design, material selection, building process, building usage, past changes to the building, and other elements related to local environmental conditions [12]. Knowledge about building pathology is used to identify conditions of deterioration and degradation of the building's condition and its components [13]. That knowledge is needed to get a relatively long period of building serviceability [7]. A building is considered environmentally friendly when its utilization is maximized and its damages are minimized [14], [15], [16].

When a building is well maintained, the period of the building's serviceability can exceed 50 years [17], [18]. This study aims to estimate the quality of construction condition of the cultural heritage building GPIB Immanuel Church at Medan Merdeka Timur Street No. 10, Central Jakarta as well as determine the cause and effect of damages in building components. The study also aims to do an economic overview of building maintenance and conservation.

II. METHODS/MATERIALS

The research includes a quantitative study conducted by weighing the building components and assessing the building's condition and evaluating the reliability of the building and its maintenance conditions. The economic forensic analysis will be carried out by examining the maintenance and cleaning costs as well as the building conservation fund.

The material used in this study is a blueprint of GPIB Immanuel Church, a building moisture meter, a digital distance meter, a digital camera, a laptop computer, and a drone to take images of the building's roof. The steps of the research are as follows:

1. observe the condition of the building structure, interior, and exterior,
2. locate the damage and identify its type in terms of architecture and maintenance management,
3. investigate the building components that have been repaired, and
4. collect secondary data on building maintenance and cleanliness costs and conservation funds.

The data analysis was conducted in two stages:

1. Weigh each building component to determine the building components' priority scale according to the BRE Digest 268 from 1988 [11].
2. Test the reliability of buildings with a scoring and weighting system and obtain the reliability score of construction and building components based on the BRE Digest 268 from 1988 [11].

The value of the building's reliability was obtained using Equation (1) :

$$\text{Building reliability} = \frac{\text{Total Weight Value}}{500} \times 100 \quad (1)$$

Then, the category of building maintenance conditions is assessed based on the results of the building reliability calculation [19] presented in Table 1.

Table 1.
Assessment of architectural weights of construction components

Reliability value	Maintenance condition
81 – 100	Good
61 – 80	Moderate
41 – 60	Minor damage
21 – 40	Medium damage
0 – 20	Severe

III. Results and Discussion

GPIB Immanuel Church is a classic European-style building that is predominantly white (Fig. 1). This church building is at Medan Merdeka Timur Street No.10, Central Jakarta. The building was built in 1839 following the design by J.H. Horst. The church was built close to the city square, which was built to be close to the governor's residence. The building is located in the Gambir Sub-district area, a national government zone, and according to the regional spatial planning and zoning regulations of DKI Jakarta Province No. 1, as of 2014, 19 cultural heritage buildings need to be preserved within the national government zone. The emergence of modern buildings in that region is not expected to affect the existence of cultural heritage buildings.

Figure 1. GPIB Immanuel Church from the front side *(source: https://www.expedia.co.id/Gereja-Immanuel Jakarta.d6291979.Tamasya)*

At the entrance of the church, there are stairs made of natural stones. The building of the church is made of bricks as significant materials, while the walls and pillars are made of a mixture of bricks, limestone, cement, and sand. The floor of the church is made of marble, while benches are made of teak wood. The church has a rectangular foyer with Palladian architecture pillars supporting the horizontal beams. However, in the north and south, the foyers have round shape following the shape of the building. At the dome, there is a round tower decorated with a lotus-shaped with six leaves. There are no supporting pillars in the middle of the main room. There are only windows and walls that support the dome (Fig. 2).

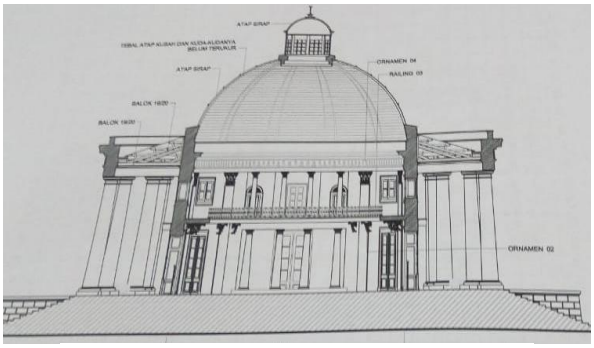

Figure 2. Sketch of the Immanuel GPIB Building *(Source: Own sketch)*

A. Building Reliability

An assessment of the construction components' weights of the GPIB Immanuel Church, i.e., the architecture (design) and maintenance, is presented in Table 2. Weight differences exist between design and maintenance. A comparison of the maintenance conditions results with those of architecture (design and construction) determined the reliability of the construction components. The result for each construction component is based on its score multiplied by its weight [11].

Table 2.
Weight assessment on building construction components

No.	Construction components	Weight (%)	
		Archi-tecture	Main-tenance
1	Roof coverings	8.1	6,7
2	Flat roof and Chamfer	10.1	12.1
3	Doors and Windows	8.7	7.8
4	Utility elements	8.5	6.8
5	Floor	7.4	7.7
6	Ceiling	7.8	6.8
7	Massive wall	9.5	8.6
8	Outer wall surface	6.4	9,6
9	Partition wall (interior)	8.4	10
10	Wallcoverings	6.1	7.4
11	Stairs	5.1	3
12	System of construction structure	9.5	6.7
13	Ornaments	4.4	6.8
		100	100

The results of the reliability examination of the church's construction components presented in Table 3 show a decrease in quality.

Table 3.
Reliability examination of building construction components

No.	Construction components	Weight (%)		Increasing/ (Decreasing) (%)
		Architecture	Maintenance	
1	Roof coverings	40.5	16.2	(24.3)
2	Flat roof and Chamfer	50.5	30.1	(20.4)
3	Doors and Windows	43.5	34.8	(8.7)
4	Utility elements	42.5	34	(8.5)
5	Floor	37.0	29.6	(7.4)
6	Ceiling	39.0	23.4	(15.6)
7	Massive wall	47.5	47.5	0
8	Outer wall surface	32.0	25.6	(6.4)
9	Partition wall (interior)	42.0	33.6	(8.4)
10	Wallcoverings	30.5	18.3	(12.2)
11	Stairs	25.5	15.3	(10.2)
12	System of construction structure	47.5	28.5	(19.0)
13	Ornaments	22.0	17.6	(4.4)
		100	40.5	16.2

The highest decrease is in the roof coverings (24.3%). The next highest item is the flat roof and the chamfer (20.4%), followed by the construction structural system (19.0%). Based on the examination, the reliability value of the GPIB Immanuel Church is 70.9, with moderate maintenance conditions (see Table 1).

B. Factors Affecting Construction Components

Factors affecting each component of the GPIB Immanuel Church construction are presented in Table 4.

Table 4.
Factors affecting building construction components

No.	Construction components	Maintenance condition	Affecting factors *)
1	Roof coverings	Medium damage	a, b, c, d, e, f, g
2	Flat roof and Chamfer	Minor damage	a, b, c, d, e, f, g
3	Doors and Windows	Moderate	a, b, c, d, e
4	Utility elements	Moderate	a, b, c, d, e, f, g
5	Floor	Moderate	b, c, d, e, g
6	Ceiling	Minor damage	a, b, d, g
7	Massive wall	Good	a, b, c, d, e, f, g
8	Outer wall surface	Moderate	a, b, c, d, g
9	Partition wall (interior)	Moderate	a, b, d, f
10	Wallcoverings	Minor damage	a, b, c, d, e, g
11	Stairs	Minor damage	d
12	System of construction structure	Minor damage	a, b, c, d, e, f, g
13	Ornaments	Moderate	a, b, c, d, g

*) *(a) Sun and light; (b) Temperature, wind, air circulation; (c) Rain; (d) Sand, dust; (e) Winds, storms;(f) Earthquake; (g) Biology factors.*

C. Roof Coverage, Flat Roof, and Chamfer

The GPIB Immanuel Church's roof is dome-shaped and is covered by wood shingles and zinc (Fig. 3). The quality of the wood shingles covering the dome has decreased and caused seepages. It is caused by rainwater, solar radiation, and air pollution. Also, it is caused by wild plants growing on top of the flat roof and chamfer due to a thick layer of dust and soil pollution. The roof coverings show medium damage while the flat roof and chamfer show minor damage (see Table 4).

Figure 3. The roof of GPIB Immanuel Church

D. Doors and Windows

The church's doors are made of high-quality teak. Most are painted yellow-white, but some are painted brown. The windows are also made of quality teak and are painted yellow-white. They are large enough that those on the building's façade leave a striking impression. It was found that the damage to the door and window components was caused by the shrinkage of wood due to solar radiation and rainwater humidity. At the time of the study, the humidity around the doors and windows (indoors) on the first floor was 70.6–73.0%, with a temperature of 30–31°C.

Meanwhile, the doors' and windows' moisture content was 6.7–7.6%. On the second floor, the humidity in the door and window area was 69.4%, with a temperature of 32°C and a moisture content of 6.9%. The damage to the door and window components is moderate.

E. Utility Element

The utility element observed was the Air Conditioner (AC). Damage to utility elements is usually caused by usage and damage to the connection between the chamfer and the pipeline (Fig.4). The damage is moderate.

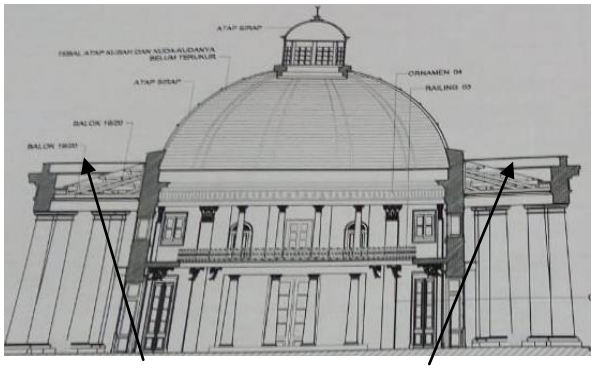

Figure 4. Construction connection on a chamfer

F. Floor and Ceiling

The distance between the floor and ceiling is about 3 metres high, thus reinforcing the building's monumental appearance. The ceiling is made of white asbestos while its decoration is made of dark brown teak. Considerable damage to the ceiling was observed. The damage was caused by humidity due to seepage and the splashing of rainwater on the dome through the glass window. The damage to the ceiling was minor.

G. Massive Walls, Inner and Outer Walls

The church's massive wall, consisting of the main building wall and a podium, is built of white bricks. Due to the building's old age, its surface is porous. Its declining condition has also been caused by rainwater and solar radiation. The seepage of rainwater between the bricks has caused humidity in the wall that has been worsened by the seepage of groundwater. However, the massive wall's condition is still good.

The inner wall is still in its original shape, and its size and materials remain the same. Even though its treatment is inadequate, the wall's quality and its coating are messy. These problems could be caused by sloppy renovation and rainwater seepage. The damage is minor while its coating is in moderate condition (Fig. 6).

The surface of the outer wall of the GPIB Immanuel Church is white. Even though the wall is clean, its paint is uneven. This unevenness was due to a failure to peel and scrape properly during repainting, which made the paint thick. However, the outer walls' condition is moderate (Fig.7).

H. Stairs

The GPIB Immanuel Church has four main stairs in its corners (Fig. 8). Both the stairs outside and inside the building are in poor condition and unsafe.

Figure 6. Damage on the inner wall

Figure 7. Damage on the outer wall surface

The wooden second inner staircase next to the front of the podium is heavily damaged. It needs to be repaired immediately since worship activities are routinely carried out on the podium. The staircase inside the church is made of good quality teak, as are the doors and the windows. Since these stairs are always exposed to humidity and are poorly maintained, their life has been decreased. However, the damage is minor.

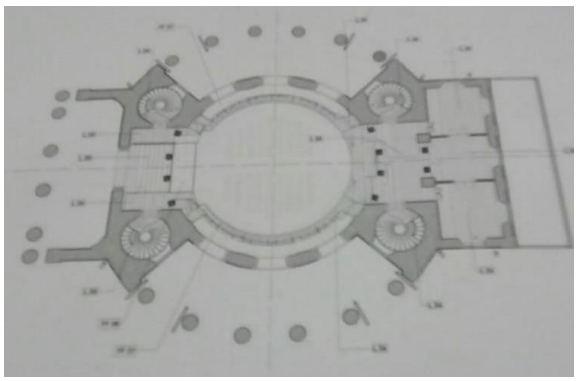

Figure 8. Position of the stairs of GPIB Immanuel Church

I. Construction Structure System and Ornaments

The construction structure system (tie beam surface, column, and roof) has changed, specifically the domed roof's composition. Previously, it only comprised wooden shingles, but now it consists of a combination of wooden shingles and zinc/metal spandex. Presently, land subsidence has led to the tie beam surface being penetrated by rainwater, which has in turn caused the building to deteriorate. This damage to the construction frame system is minor.

The building's plain ornaments are dirty, likely because of air pollution. Besides, previous renovations might have been substandard. This damage to the ornaments and building's construction components is minor.

J. Maintenance and Cleaning Cost

Maintenance has an important role in the production and durability of the architecture of the building. However, most architects pay less attention to it in their design. Sample (2016) explained that architects need to apply a concept of maintenance architecture, by explaining the concept of maintenance in their designs, through the knowledge of building materials. The maintenance and cleaning service costs for GPIB Immanuel Church from 2016 to 2018 are presented in Table 5. The data shows that the cost increased each year. Maintenance costs can be reduced by utilizing natural ventilation—a passive method that is highly recommended for environmental control. During the design and construction process, it is necessary to think about how the building can make the best use of energy sources from the environment. Therefore, architects and contractors must know about green building technology.

Table 5.
Maintenance and cleaning costs

Month	Maintenance and cleaning costs		
	2016	2017	2018
January	n/a	11.386.000	12.553.000
February	n/a	10.810.000	12.500.000
March	n/a	10.653.000	15.349.000
April	n/a	10.825.000	13.074.000
May	n/a	13.054.000	20.142.500
June	9.753.000	10.552.000	12.550.000
July	15.693.000	10.020.000	12.860.000
August	35.883.500	10.400.000	19.558.000
September	46.438.000	22.313.000	37.101.000
October	16.003.000	28.390.000	19.226.000
November	13.308.000	24.958.000	18.498.500
December	12.686.500	16.139.000	12.500.000
Total	149.765.000	179.500.000	205.912.000

n/a = not available

K. Conservation Fund

It is evident from looking at the church building that it is still in need of conservation work. The Burra Charter states that conservation is the process of managing a place or object so that the cultural meaning contained in it can be well preserved [20]. The conservation process for Immanuel Church includes restoration, reconstruction, and adaptation. Conservation is especially important for the roofs, ceilings, columns, floors, doors, windows, walls, stairs, and structural systems. The conservation work should be carefully planned and involve consultation with experts who know the type, quality, and age of the building materials used. It will also be necessary to consult with cultural heritage experts to maintain the sustainability of the church. Honesty and authenticity are also important principles that must be applied. Also, the conservation activity must pay attention to sustainability in the past, the present, and the future.

The conservation funds spent over three years (2016–2018) amounted to Rp 2,384,755,011 (Table 6). The highest-spending occurred in 2018 and the lowest in 2017, with an average amount spent per year Rp 794,918,337. As of February 2019, the total balance of conservation funds collected from the congregation was Rp 435,096,692. Therefore, more funds are needed to continue the conservation work on the church.

Table 6.
Conservation fund

Month	Use of conservation funds		
	2016	2017	2018
January	n/a	0	0
February	n/a	306.850.750	0
March	n/a	0	575.278.691
April	n/a	0	0
May	n/a	0	130.848.907
June	0	0	0
July	288.512.000	0	415.741.570
August	0	66.391.153	0
September	0	0	0

October	266.599.000	0	0
November	0	0	190.364.743
December	144.168.188	0	0
Total	699.279.188	373.241.903	1.312.233.920

n/a = not available

IV. Conclusion

Building pathology, including diagnosis and forensic treatment, is used to determine the level of deterioration in a building and its components. The results of the inspection of the components of GPIB Immanuel Church can be categorized using a rating scale running from "lightly damaged" to "severely damaged." Components included in the "lightly damaged" category are doors, windows, floors, massive walls, interior dividing walls, and ornaments. Components included in the "medium damage" category are flat roofs (specifically the concrete plates and gutters), utility elements, ceilings, outer wall surfaces, wall coverings, and the structural system (specifically tie beam surfaces, columns, and roofs). Components included in the "heavily damaged" category are the roof and ladder covers. The roof's shingle dome cover has deteriorated considerably.

The conservation process of the GPIB Immanuel Church building includes the processes of maintenance, preservation, restoration, reconstruction, and adaptation. Conservation work needs to be carried out on roofs, ceilings, columns, floors, doors, windows, walls, stairs, and the structural system. The measurement results indicate that the building's safety rating is 70.9% with moderate treatment conditions. This indicates that conservation work needs to be continued after 2018.

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