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Evaluation of the Performance of Green Buildings at Al-Hidayah Mosque, Bandung City

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ABSTRACT

Buildings are designed to fulfil the needs of human activities. However, excessive carbon emissions due to development activities may contribute to the accumulation of heat on Earth. The concept of green building emerged as an effort to overcome this by optimising passive strategies through environmentally friendly architectural design. On the other hand, a large number of mosques have been built in the city of Bandung to tend to the religious needs of Muslims. The design of mosques that use green building concepts will help achieve government targets in the field of sustainability. One type of mosque that is often found in Bandung are mosques located in urban villages. This research aims to determine the performance from a green building aspect of an urban village mosque with a case study of Al Hidayah Mosque located in Cidadap District, Bandung. This research uses a descriptive method with a quantitative approach. The data needed for this research was obtained by observing and recording data directly on the object of research. Data collection is also carried out by observation, measurement, and interview methods. The data obtained was then analysed based on the green building performance parameters set by the government through PERMEN PUPR No. 21 of 2021. From the results, it is concluded that Al-Hidayah Mosque has not fulfilled the minimum criteria of a green building. These results are expected to be used as a reference in designing mosques in urban villages and as a basis for the city government to establish policies related to mosque buildings in urban villages.

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1. INTRODUCTION

Buildings are a physical structure resulting from a construction project that is integrated with its surrounding environment, either partially or entirely above ground, on the ground, and under water. The building functions as a place for people to carry out various activities, including residence, worship, business, social activity, cultural, and other special activities. A Building acts as a vessel to facilitate human daily activities. However, building construction activities have the potential to contribute more than 40% of carbon gas emissions on earth (Ervianto, 2012). Numerous development activities can contribute to the accumulation of heat on Earth, which can cause environmental damage. Based on statistical (Climate Watch, 2021). Indonesia produces 1475.83 million tons of carbon emissions (3.11% of the world's carbon emissions). 23.2% of this figure is due to industrial and construction activities. The concept of green buildings emerged as an effort to overcome the phenomenon of global warming by utilizing resources effectively. Based on Vale B. & Vale R., (2014) Green buildings consist of five main criteria: energy savings, taking advantage of climatic conditions, responding to site conditions, paying attention to users, and minimizing new resources.

Green building has been implemented in the Indonesian government since 2009 with the establishment of GBCI (Green Building Council Indonesia). The GBCI Institute publishes a green building assessment standard called Greenship. The issuance of the standard aims to provide a clear, systematic framework for assessing the performance of green buildings. The Indonesian Government itself issued regulations regarding the performance standards of green buildings in the PERMEN PUPR (2021). The implementation of the Ministerial Regulation can be seen in the Buildings in IKN. Several other buildings have also received Green Building certificates set by (Green Building Council Indonesia, 2012).

Bandung is one of the major cities in Indonesia with a population of around 2.5 million people. According to Global Forest Watch (2021). Bandung itself produces 1.2 kilotons of carbon emissions every year. Mosques are a type of building that has a large number and are spread throughout the city of Bandung, with a total of 2,908 units (Badan Pusat Statistik, 2021). Bandung is one of the cities where the majority of the population is Muslim, so the construction of mosques has the potential to increase every year. The increase in development activities leads to greater release of carbon dioxide emissions into the environment. The Indonesian government has encouraged the implementation of green building principles through the Ecomasjid program. However, the program has not been able to be realized evenly due to limited land and resources in 60% of the area in the city of Bandung.

The area is a city village area that has characteristics of densely arranged buildings and narrow road access, resulting in limited land availability. This research was conducted to determine to what extent one of the village mosques in Bandung can meet the principles of green building. Al-Hidayah is a jami mosque located in the Ciumbuleuit area, Cidadap District. The Al-Hidayah Mosque building was first constructed on Ranca Bulan I Street in the 1980s to meet the worship needs of Muslims in the area. The Al-Hidayah Mosque not only functions as a religious place but also as a space where the local community can gather (Hefni, 2017).

The essence of green buildings is to create a friendly environment to both nature and its users. A building can be categorized as a green building if it meets the established standards and receives certification from a relevant authority based on specific assessment criteria (Prasustiawan et al., 2023).

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Figure 1. Al-Hidayah Mosque
Source: Author, 2024

The purpose of this study is to asses the suitability of the performance of green buildings at the Al-Hidayah Mosque in accordance with standards set forth in the Minister of Public Works and Public Housing Regulation Number 21 of 2021 concerning the Performance Assessment of Green Buildings. The benefit of this research is to broaden insight and enrich the idea of methods for both students and architects in the application of the green buildings concept in mosques fuctions. It is hoped that this research can serve as a reference for similar studies or be used as a guide for design in similar site conditions.

2. LITERATURE REVIEW

Various environmental and natural issues occurring today, including global warming, have become an increasingly evident phenomenon. Global warming itself refers to the increase in the average temperatures in the atmosphere, land, and oceans on the Earth's surface. One of the causes is the construction of buildings, which contributes to the greenhouse effect (Pratama, 2019).

Global warming, climate change, and the large-scale of exploitation of natural resources have resulted in environmental degradation and the diminishing of natural resources. Therefore, the concept of green buildings exists as one of the solutions to prevent further damage. Green buildings are not only viewed in terms of final result, but also encompass the entire planning and construction process. The success of a construction project greatly depends on the quality of the individuals involved in its implementation, especially those who hold key roles in the project (Mulyadi, 2012).

One way to adress this by applying the concept of green building or environmentally friendly buildings, especially in the process of constructing buildings in Indonesia which continue to grow rapidly along with the energy demand. Green buildings refer to construction that have measurable performance in terms of energy efficiency, water conservation, and the utilization of other resources. (Mahyuddin et al., 2020).

This study discusses the application of green buildings in mosque buildings. The discussion in this study is supported by several theoretical studies, including the Definition of Green Buildings, Green Buildings according to the Minister of Public Works and Housing Regulation No. 21 of 2021, and Natural Lighting.

2.1. Definition of Green Building

Green building is a design approach that primarily focuses on creating designs that address environmental impacts by utilizing natural resources effectively. A green building is a design concept where the building is designed to maximize energy conservation, protect the surrounding environment, and efficiently utilize space in harmony with nature throughout its lifecycle (Hong & Minfang, 2011). According to the definition, a green building is an

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environmentally friendly structure designed in accordance with principles and criteria of sustainable design throughout its implementation process (Tiagas dan Doly H, 2017).

Several terms related to the concept of green building include high performance, bioclimatic design, climate responsive or passive design, sustainability, vernacular or traditional architecture, zero waste building, low carbon building, and smart building. The terms mentioned above represent an approach that can be utilized to realize green buildings. (Patki et al., 2019). Currently, the concept of green buildings has been formulated into a rating system implemented by various related organizations. The assessment is measured through ranking based on a set of specific criteria and indicators (Nugroho, 2011).

2.2. Green Buildings According to PERMEN PUPR No. 21 Tahun 2021

Minister of Public Works and Housing Regulation No. 21 of 2021 (PERMEN PUPR No. 21/2021) is a set of regulations issued by the government to provide technical guidance regarding the performance of green buildings in Indonesia. The purpose of this regulation is to establish construction standards that support environmental sustainability and energy efficiency. According to PERMEN PUPR No. 21/2021, a green building is a structure that has met the Technical Standards for Building Constructions and has achieved a significant performance rating in terms of energy savings and efficient use of other resources, under its designated functions and typologies.

Based on PERMEN PUPR No. 21/2021, the performance assessment of green buildings is evaluated based on seven parameters, namely Site Management, Energy Efficiency, Water Efficiency, Indoor Air Quality, Use of Environmentally Friendly Materials, Waste Management, and Wastewater Management. These seven parameters serve as criteria that determine the rating of a green building, which includes three levels, as shown in Table 1 below:

Table 1. Predicate Level in PERMEN PUPR No. 21 Tahun 2021

Predicate	Percentage
Pratama	45% - 65%
Madya	65% - 80%
Utama	80% - 100%

Source: PERMEN PUPR No. 21 of 2021

2.3. Natural Lighting

Natural lighting refers to the use of light from natural lighting sources such as sunlight, moonlight, and starlight. (Dora & Nilasari, 2011). Natural lighting utilizes sunlight to illuminate a space, thereby reducing electricity consumption. By relying on natural sunlight as a source of lighting, buildings can reduce their dependence on non-renewable energy sources, thus decreasing greenhouse gas emissions.

The utilization of natural lighting greatly depends on the quality and distribution of light entering through windows or openings, as well as the orientation of the openings. The larger the opening, the more light can enter the space, thus requiring control over the intensity of light received. Furthermore, the quality of natural lighting is also influenced by the position of the openings in relation to the direction of incoming sunlight.

According to the National Standarization Agency (2000) the National Standardization Agency (2000), natural lighting during the day can be considered optimal if it meets seceral criteria, (a) between 08.00 and 16.00 local time, there is a sufficient amount of light entering the room, and (b) the distribution of light within the room is uniform and does not cause distruptive glare.

The larger the opening, the more light is received. The quality of natural lighting can also be influenced by the position of the opening relative to the direction of sunlight. According to

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(Ornam, 2010), The goal of natural lighting is to create an optimal level of illumination so that tasks can be performed more easily without causing visual discomfort. At least two important aspects are required to achieve visual comfort with natural lighting:

1. Illumination Quantity refers to the amount of light received by a visual object.
2. Illumination Quality.

Other aspects that are inseparable from the quantity and quality of lighting in a space include:

- Room Index, the proportion of space.
- Ceiling Height.
- Colors and textures conditions used in the elements that form the space.

3. METHODS

This study employs a descriptive-evaluative research method with a quantitative approach to analyze the performance success of green building design in the case study of the Al-Hidayah Mosque. The descriptive method is implemented to present all research findings with a clear and systematic description. The evaluative method is used to assess the alignment of the green building performance in case study with the criteria outlined in PERMEN PUPR No. 21 of 2021 standards. The data required for this study were obtained through direct observation and data recording at the study site. Data collection was carried out using the following methods:

1. **Observation**
   According to Sudjana (1989), observation is a systematic activity of observing and recording the phenomena under investigation. In this research, observations were conducted to gather data on the characteristics and physical condition of the building, the usage of the mosque building, and the surrounding environmental conditions.
2. **The Measurement**
   The measurement method is a data collection technique involving the measurement of specific units using appropriate instruments following the variables being examined. In this study, the numerical data include light intensity (measured with a Lux Meter), air temperature and humidity (measured with a Wet Bulb Globe Thermometer), and wind speed (measured with a Hot Wire Anemometer). Measurements were conducted at 24 points determined based on the position of the building openings.

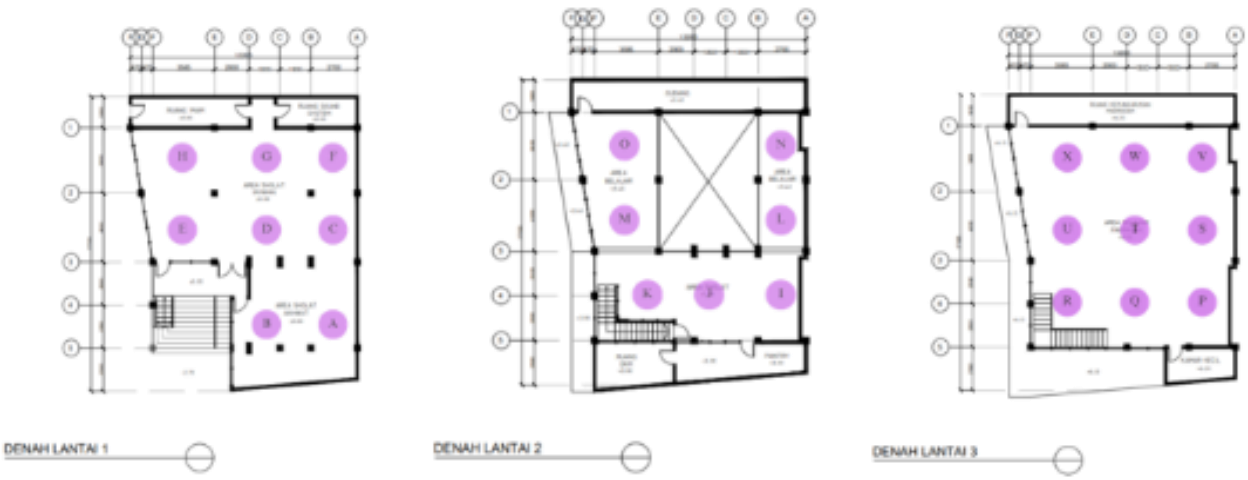

Figure 2. Measurement Point Map
Source: Author Analysis, 2024

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The measurement process was carried out on three consecutive observations to determine the comparison and average values. The lighting and wind measurements were taken between 10.00 AM to 04.00 PM, while temperature and humidity were measured from 10.00 AM to 07.30 PM.

3. **Interviews**
   The interview method is a data collection technique that involves a guided conversation and question-and-answer process to achieve a specific objective. In this study, interviews were conducted solely to validate data regarding the building's history, physical condition, and its usage by the occupants. The interviewee was the Head Management Board (DKM) of Al-Hidayah Mosque.

All the information obtained from the data collection phase was analyzed by comparing it with the provisions outlined in PERMEN PUPR No. 21 of 2021. The performance analysis of green building at the Al-Hidayah Mosque was conducted with reference to the performance assessment parameter table included in PERMEN PUPR No. 21 of 2021.

4. RESULT AND DISCUSSION

The obtained data are analyzed and evaluated in accordance with the provisions outlined in the Minister of Public Works and Housing Regulation No. 21 of 2021 to determine the suitability of the green building performance of the research object. The performance evaluation of the Al-Hidayah Mosque was conducted based on the seven parameters specified in the regulation. These parameters include site management, energy efficiency, water efficiency, indoor air quality, the use of environmentally friendly materials, waste management, and wastewater management (Ofori, 2013).

4.1. Site Management

Site management involves spatial planning that considers natural factors within the site and its surrounding environment to facilitate the development of more environmentally friendly buildings.

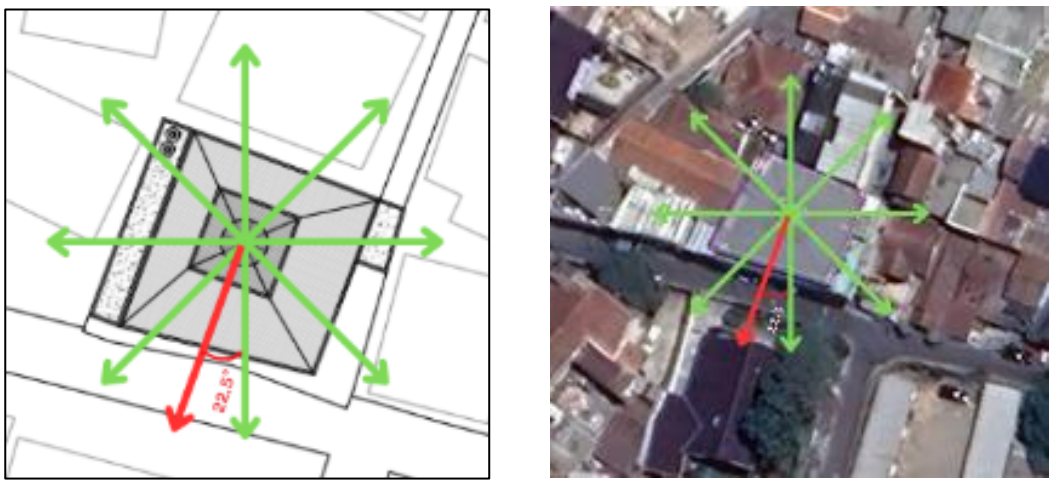

Figure 3. Orientation of Al-Hidayah Mosque Building
Source: Analysis, 2024

The building is oriented towards the west, with its shortest wall located on the east side and the longest wall positioned on the south side at an angular slope of 22.5 degrees relative to the north-south axis. The building features openings on the east and south sides, allowing for the optimal incorporation of natural light from morning to evening.

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Table 2. Calculation of Mosque Albedo Value

Material	Albedo	Area (m²)	Total Albedo
Building Roof Covering			
Spandex Roof	0.61	165.3	100.8
Concrete Roof	0.5	66.5	39.9
Zinc Aluminum	0.85	14	11.9
Mosque Land Paving			
Asphalt	0.15	25.1	3.8
Amount		270.8	156.4
Total Albedo Value		0.58	

Source: Survey, 2024

Based on the provisions outlined in the Minister of Public Works and Housing Regulation No. 21 of 2021, a building must have a minimum albedo value of 0.3. As shown in Table 2, the Al-Hidayah Mosque has a total albedo value of 0.58, thereby meeting the criteria for a green building.

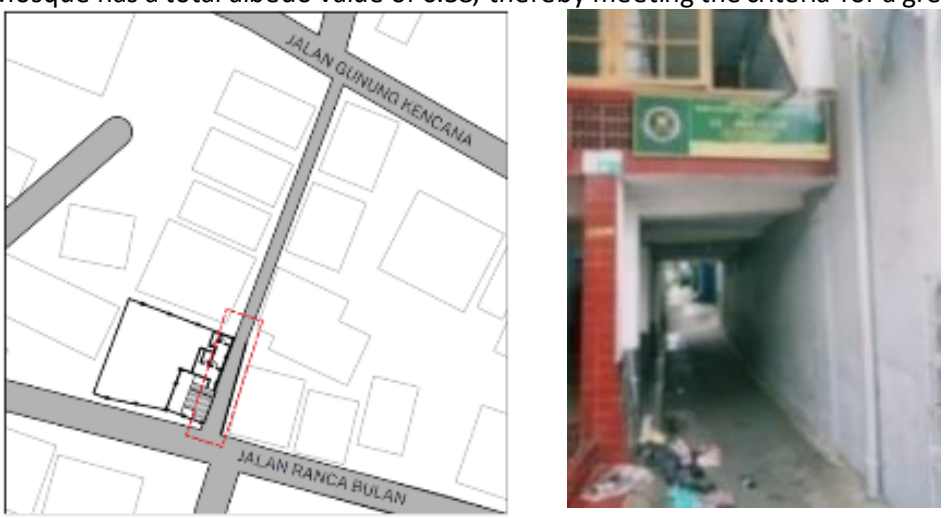

Figure 4. Al – Hidayah Mosque Corridor
Source: Analysis, 2024

The pedestrian path within the mosque area is an alleyway located on the east side of the building. Due to the limited land area, the available space is maximized for building purposes. To improve accessibility from Jalan Ranca Bulan and Jalan Gunung Kencana, a portion of the mosque's land was donated for the creation of an alleyway. However, to ensure optimal land utilization, the first to third floors extend over the alley

4.2. Energy Efficiency

The building is not designed to incorporate an air conditioning system. Instead, it utilizes the cool weather conditions by maximizing openings, such as windows and ventilation holes, to maintain thermal comfort. Additionally, the building features voids between floors, which enhance indoor air circulation. Mechanical ventilation is employed when natural ventilation proves insufficient to ensure user comfort. To support the research findings, measurements were conducted to assess the building's air conditioning performance.

Table 3. Temperature, Humidity, and Wind Speed Measurement Results

Assessment Aspects	**SNI 03-06572-2001**	**Avg Floor 1**	**Avg Floor 2**	**Avg Floor 3**
Air Temperature (°C)	25°C ± 10	26.5	26.4	26.7
Humidity (%)	55 % ± 10	75.9	76	74.7
Wind Speed (m/s)	0.15 – 0.25	0.0	0.0	0.0

Source: Survey, 2024

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Based on Table 3. Al-Hidayah Mosque meets SNI 03-06572-2001 for air temperature aspects. However, the building still does not meet the standards in terms of air humidity and wind speed in the room.

Table 4. Window at Al-Hidayah Mosque

Window Floor 1	Window Floor 2	Window Floor 3
		

Source: Survey, 2024

Openings not only facilitate natural ventilation but also allow natural light to enter the building. The number and placement of openings optimize daylight utilization from morning to evening (Table 4). On the first floor, the openings include operable windows and fixed windows, located on the south and east walls. The windows on the first floor are classified as central windows, which effectively capture natural light. Their wide design ensures even illumination throughout the space.

On the second floor, the openings consist of operable windows, fixed windows, and glass blocks. The windows on this floor are also wide, allowing sufficient daylight penetration to meet the lighting needs of the madrasah.

On the third floor, fixed windows are located on the south and east walls. These windows are positioned 100 cm above the floor and have a height of approximately 180 cm. Compared to the windows on the first and second floors, the third-floor windows are taller and wider, enabling greater daylight entry into the building.

To support these findings, measurements of natural lighting levels were conducted within the building

Table 5. Natural Light Intensity Measurement Results

	Avg Floor 1	Avg Floor 2	Avg Floor 3
Light Intensity (Lux)	691	1157	1779

Source: Survey, 2024

Based on the measurement results, all measured points met the minimum light intensity standard of 200 lux. The third floor receives the highest amount of sunlight, with an average intensity of 1,779 lux. The second floor follows with an average of 1,157 lux, while the first floor receives the least light, averaging 691 lux (Table 5).

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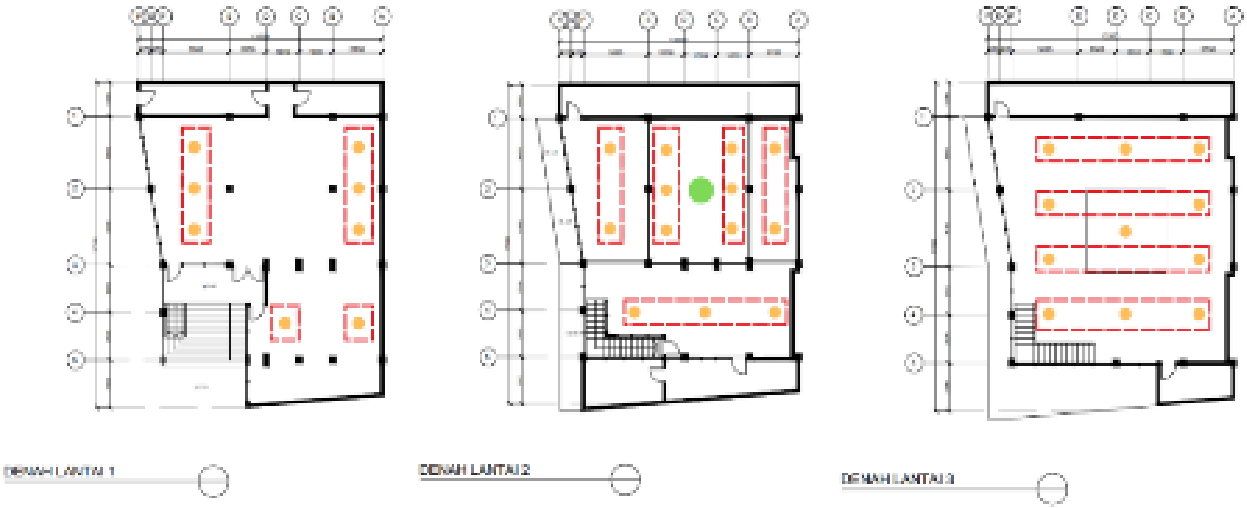

Figure 5. Grouping of Lights at Al-Hidayah Mosque
(Source: Analysis, 2024)

This building also implements a lighting grouping system based on the availability of natural light. As shown in Figure 4, the lighting on the first and second floors is grouped to distinguish areas that receive sufficient natural light from those that do not. However, the lighting on the third floor does not follow this grouping system, making it less energy-efficient.

According to SNI 03-6197-2020, the artificial lighting specifications in the mosque meet the standards, as the building uses energy-efficient lighting, such as LED lights with appropriate color temperatures. However, the lights in the mosque are manually operated using switches and do not incorporate occupant or lighting control sensors, failing to meet the standard requirements in this aspect.

The Al-Hidayah Mosque consists of four floors: the ground floor serves as an ablution and utility area, the first floor as the main prayer area, the second floor as both a prayer area and madrasah, and the third floor as a madrasah area. The building is designed without electric vertical transportation, such as elevators or escalators, which enhances its energy efficiency.

The mosque utilizes various electrical equipment, including lighting, fans, water pumps, computers, refrigerators, and sound systems. However, it does not implement an electrical load grouping system and lacks a kWh meter for each function category. Based on interview results, the mosque consumes an average of 568 kWh per month or 18.9 kWh per day. When calculated based on actual electricity needs, the mosque requires a minimum of 11.4 kWh per day. Since the power consumption exceeds this value, the building's electricity usage is considered inefficient

4.3. Water Use Efficiency

The clean water supply in the Al-Hidayah Mosque originates from a well that was specifically constructed to meet the mosque's needs. However, the building's clean water distribution system is not equipped with a meter at the water output, making it impossible to monitor water usage. Additionally, the building does not utilize water-efficient sanitary fixtures.

4.4. Indoor Air Quality

The interior of the mosque is designated as a smoke-free area, while outdoor spaces such as balconies are permitted for smoking. However, it was found that the building does not provide no-smoking signs. According to SNI 03-6572:2001, the total opening area in a building must be at least 5% of the floor area. In this building, the ratio of openings to floor area is 15% on the first floor, 11% on the second floor, and 8% on the third floor, meeting the required standards. However, the Al-Hidayah Mosque is not equipped with CO_2 and CO sensors for indoor spaces, making it non-compliant with the standards for optimal carbon dioxide and carbon monoxide control.

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4.5. Use of Eco-Friendly Materials

The wall covering materials in the building consist of red brick and lightweight brick, where red brick is used from the ground floor to the second floor, while lightweight brick is used for the third-floor walls. Both types of bricks are sourced from suppliers in Bandung, classifying them as locally sourced building materials.

According to the PUPR Regulation No. 21 of 2021, environmentally friendly materials are those that are locally sourced within 1,000 km of the project site, free from toxic and hazardous substances, and produced in compliance with ISO 14001 standards. The Al-Hidayah Mosque uses Mowilex and Propan paint products for its walls, with Mowilex applied on the ground, first, and second floors, while Propan is used on the third floor. Based on the data obtained, both paint products do not contain harmful metals and have minimal toxic and hazardous substances, meeting the criteria for environmentally friendly materials.

The structural elements of the Al-Hidayah Mosque consist of reinforced concrete and wide-flange (WF) steel. Reinforced concrete structures are present on the ground, first, and second floors, whereas WF steel structures are used on the third floor. Based on interview results, the raw materials for the concrete used in the building were sourced from Bandung, making them locally sourced. However, the building's concrete structure was formed in the 1980s, before the implementation of the ISO 14001 environmental management system, which was introduced in Indonesia in the late 1990s.

4.6. Waste Management

The mosque has a private garbage disposal system, with waste bins placed inside the building. Waste generated by the mosque is collected and sorted into organic and inorganic categories before being transported to the local village collection point. However, the building's waste management system has not implemented the 3R (Reduce, Reuse, Recycle) principle or recorded waste generation data, resulting in the absence of a score for these criteria.

4.7. Waste Water Management

The wastewater treatment system at Al-Hidayah Mosque is divided into two categories. Greywater is discharged directly into the local drainage system without prior treatment, eventually flowing into the Cikapundung River. Meanwhile, blackwater is managed through a septic tank. The building has not implemented any initiatives to recycle domestic wastewater for reuse. Currently, wastewater generated by the building is designed to be directly channeled into local sewers.

4.8. Recapitulation of Green Building Performance at Al-Hidayah Mosque

Based on Table 6, the Al-Hidayah Mosque obtained a total score of 32.7% of the overall points, as assessed according to the parameters outlined in the Minister of Public Works and Housing Regulation No. 21 of 2021 on Green Building Performance Assessment.

Table 6. Assessment of Energy Use Efficiency Aspects

Aspects & Criteria	Percentage Fulfilled (%)
Site Management	21,1
Energy Efficiency	56,5
Water Use Efficiency	0
Indoor Air Quality	42,1
Use of Eco-Friendly Materials	47,6
Waste Management	0
Wastewater Management	16,7
TOTAL VALUE	**32,7**

Source: Survey, 2024

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5. CONCLUSIONS

Based on the results of the review and analysis, it was found that, overall, the Al-Hidayah Mosque has not fully implemented green building principles. The mosque obtained a score of 32.7% of the total points, which does not meet the minimum requirement of 45% for Green Building certification.

The findings indicate that buildings located in close proximity to other structures face challenges in implementing green building principles. However, several recommendations can still be proposed to enhance the mosque's green building performance:

1. Buildings can incorporate light sensors for lighting groups located in areas exposed to natural daylight. The implementation of light sensors can optimize energy consumption by adjusting light intensity according to natural lighting conditions.
2. Buildings can install water meters in the groundwater output system to monitor and optimize water usage efficiency.
3. Buildings can utilize water-saving sanitary fixtures to enhance water efficiency in the mosque.
4. Buildings may add no-smoking signs
5. The building can implement waste segregation based on organic, inorganic, and hazardous waste (B3) to facilitate the processing process.
6. Buildings can add lightning rods to the roof as a medium to conduct electricity from lightning strikes

By implementing the proposal, it was found that buildings can at least increase the performance value of green buildings to 75 points from 165 or 45.5% of the overall points. This percentage figure is enough to meet the certification requirements of the Primary Green Building. The implementation of this research was carried out to evaluate the performance of green buildings in mosque buildings in urban village areas. It is hoped that this research can be a reference for other similar research or used as a reference for the design of green buildings on similar sites.

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