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THE INFLUENCE OF MICROCLIMATE ON ARCHITECTURAL DESIGN IN THE COASTAL AREA, NORTH JAKARTA

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ABSTRACT

The microclimate has an influence on architectural design in order to produce thermal comfort. This study aims to evaluate the influence of microclimate on the architectural design of JIS, which is not far from Ancol Beach, especially wind speed. The method used is qualitatively descriptive. The result of the “wind environment study” is planting vegetation as an open space design in the concourse to reduce the high wind speed. Orientation on gate opening spreads flat across the side to optimize audience capacity. The orientation on the JIS mass slope is west-east, known as the west ramp because it has a strategic point as the entrance pedestrian walk and the east ramp as the exit pedestrian walk. On the facade, JIS has “a hole-hole design” with the primary function of air circulation to maximize the comfort of supporters in the stadium building. The building materials used are local materials, recycled materials, like legal wood products, and health-friendly materials. The albedo value calculated for the roof hardening area is 0.65, and for the non-roof hardening area, it is 0.40. The selection of materials is close to bright colors. The stadium roof frame, a construction system greatly influenced by wind, is designed using rules or mathematical formulas (parameters), making it a parametric design that simultaneously enhances aesthetic value. The implementation of the rooftop photovoltaic system at JIS serves to utilize sunlight as an energy-saving measure.

KEYWORDS: architectural design, building material, microclimate, thermal comfort, wind speed

*Iklim mikro memiliki pengaruh terhadap rancangan arsitektur agar menghasilkan kenyamanan termal. Studi ini bertujuan untuk mengevaluasi pengaruh iklim mikro terhadap rancangan arsitektur JIS yang berada tidak jauh dari Pantai Ancol, khususnya kecepatan angin. Metode yang digunakan adalah kualitatif secara deskriptif. Hasil dari “*wind environment study*” berupa penanaman vegetasi sebagai rancangan ruang luar di* concourse *untuk mengurangi kecepatan angin yang tinggi. Orientasi pada bukaan gate menyebar rata pada seluruh sisi untuk mengoptimalkan kapasitas penonton. Orientasi pada gubahan massa JIS adalah barat-timur yang dikenal dengan ramp barat karena memiliki titik strategis sebagai jalur pejalan kaki masuk dan ramp timur sebagai jalur pejalan kaki keluar. Pada fasad JIS memiliki “desain berlubang-lubang” dengan fungsi utama sebagai sirkulasi udara untuk memaksimalkan kenyamanan para* supporter *dalam bangunan stadion. Material bangunan yang digunakan adalah material lokal, material daur ulang, seperti* legal wood product *hingga materia yangl ramah bagi lingkungan. Nilai albedo yang dihitung untuk area pengerasan atap adalah 0.65, dan untuk area non-atap adalah 0.40. Pemilihan material tersebut mendekati warna terang. Sistem konstruksi yang sangat berpengaruh dari angin adalah rangka atap stadion yang dirancang dengan aturan atau rumus matematis (parameter) adalah desain parametrik yang sekaligus menciptakan nilai estetika. Penerapan* rooftop photovoltaic system *di JIS berfungsi dalam memanfaatkan sinar matahari sebagai Langkah penghematan energi.*

KATA KUNCI: *rancangan arsitektur, material bangunan, iklim mikro, kenyamanan termal, kecepatan angin*

INTRODUCTION

Theory and Concept of Responsive Environmental Architecture

Architectural design plays an important role in creating spatial needs to accommodate user activities that are comfortable for humans. To carry out activities well, comfort becomes one of the indicators in architectural design. Among the factors related to comfort is the microclimate, which is greatly influenced by physical or natural conditions. The importance of the microclimate in this study is due to its psychological and physiological effects on humans related to direct exposure. That means humans perceive comfort not only through objective measurements but also through subjective perceptions that are greatly influenced by direct experiences with the surrounding microclimate.

Adaptation and space design heavily depend on understanding the microclimate in the context of building design or spatial planning. Adjusting to the microclimate allows for the creation of a more comfortable environment passively, without fully relying on mechanical systems like air conditioning. Therefore, understanding the microclimate becomes important in comfort research that relies on natural conditions. Fundamentally, the definition of microclimate is the climatic conditions in an area with limited extent or function, but its components are mostly the same as macroclimatic conditions, namely air temperature, humidity, wind, and sunlight (Lakitan, 2002).

In realizing comfort within a building, an architect must be able to understand the state and condition of the surrounding environment and analyze it as a basis for decision-making in designing a building. Environmentally responsive architecture can be used as a solution in solving problems through planning based on the preservation of the surrounding environment. The term environmentally responsive architecture is the same as environmentally conscious architecture, eco-friendly architecture, or ecological architecture. The concept of ecological architecture is a combination of environmental science and architecture that focuses on development planning while considering the balance between the natural environment and the built environment (Firly, Setyaningsih, & Suparno, 2019). In this concept, an architectural design approach is used that combines nature with technology, using nature as the basis for design, environmental improvement so that it can be applied to produce buildings or landscapes with the application of technology in their design (Firly, Setyaningsih, & Suparno, 2019).

Comfort in relation to buildings can be defined as a state that provides a comfortable and pleasant feeling for its occupants (Karyono, 2010). To meet the comfort factor, spaces as activity containers require designs that are responsive to the surrounding environment. The environmental climate is modified by buildings into an indoor environment that directly affects the comfort of humans as users of the building. There are two main requirements for indoor climate, namely not causing stress that could potentially damage the human ecological system and providing a sense of safety for humans and the environment related to their activities. In that context, the discussion of microclimates is generally aimed at specific studies such as urban areas, rural areas, or others. Related to specific areas, this research emphasizes coastal/seaside areas, namely North Jakarta.

The Influence of Microclimate on Architecture

Climate factors have a significant influence on building design, especially concerning human factors and the need for building materials. In Indonesia, it falls under the category of humid tropical architecture, where the characteristics of location and geography are influenced by elements such as air temperature, humidity, wind, rainfall, and solar radiation, which are interdependent with one another. In the book "Climate and Architecture," it is mentioned that climate is the average weather condition in a certain area on the Earth's surface that lasts for a relatively long period. Related to the study of coastal areas, thus referring to specific regions. For example, places like the beach have humidity levels ranging from 80% to 98%, so with high humidity, actions are needed to accelerate evaporation (Frick & Darmawan, 2007). Meanwhile, the humidity that is pleasant for the body ranges from 40% to 70%.

Lippsmeier (1994) stated that generally there are three climate components that serve as parameters for determining thermal comfort, namely air temperature, air humidity, and wind. Meanwhile, Brown and Gillespie (1995) state that microclimate is the climatic condition in a very limited space, influenced by solar radiation, air temperature, air humidity, and rainfall. According to Miller (1970) in Margaretha (2007), microclimate is greatly influenced by local factors, including vegetation characteristics, small bodies of water such as lakes, and human activities that can alter the purity of the microclimate, including the intensity of solar radiation energy, surface structure with varying composite colors and characteristics on the earth's surface, land and sea distribution, as well as the influence of mountains or topography and wind.

Indonesia, as a tropical country, must consider thermal comfort factors in the planning and development of the built environment (Nolasari et al., 2023). Adjustments to the design of the built environment and appropriate architectural design can help reduce the impact of temperature and wind on thermal comfort. This is also emphasized in the location of the research in coastal/seaside areas. Referring to Imran's research (2013), the shape of buildings in each region highly depends on several factors, including (1) human activity/character, (2) location/region, (3) building orientation towards weather/climate, (4) position of the sun's movement, (5) direction of wind/air movement, (6) building orientation towards nature, (7) land position/ elevation, (8) Technological advancement, (9) Thermal comfort, and (10) Changes in human life eras.

Comfort factors are fundamental considerations that need to be accompanied by technological advancements in both concept and sophistication. In anticipating climate change, it must be controlled to enhance comfort, one of which is through passive cooling technology (Sudibyo, 1987), namely (1) adding sun shading to address direct sunlight; (2) thermal insulation for solar radiation penetrating the outer wall surface; (3) surfaces as diffusers for indirect solar radiation; (4) vegetation, roofs with ventilation for convection/airflow or fluid flow; (5) for ground surfaces that do not absorb heat, a raised floor system is used (to address radiation from the ground); and (6) thermal comfort aspects for built environment planning include building exteriors, building interiors, and building envelopes.

Architectural design plays an important role as a microclimate controller that directly affects the environment through layout design, the use of renewable energy, vegetation, material selection, and green technology. The proper layout of buildings and orientation towards the sun can optimize natural lighting and heating. The use of renewable energy sources such as solar panels and rainwater systems helps reduce dependence on fossil fuels, while vegetation around the building supports natural cooling and beautifies the environment. In addition, the selection of materials with high thermal insulation, environmentally friendly construction such as natural ventilation and high ceilings, as well as the implementation of rooftop gardens and green walls, contribute to maintaining stable room temperatures, reducing energy consumption, and improving the surrounding air quality.

The Influence of Microclimate on Humans and Their Activities

Architecture plays a significant role in creating a comfortable and sustainable microclimate, thereby directly influencing human activities within it. Within the scope of a limited area, microclimate changes are influenced by the physical elements present in that limited environment (Zahra, Sangkertadi, & Kumurur, 2021). In the process of architectural design, the influence of microclimate is focused on the aspect of human comfort within a building where activities are carried out effectively. These aspects are solar radiation, air movement, air humidity, rainfall, and average air temperature, which are important in determining the comfort of an area/region. This must also be integrated with the context of the research being conducted in coastal areas.

In its development up to now, humans continue to learn to manage the interaction of their buildings with the surrounding climate conditions that are suitable for their lives. Therefore, energy-efficient buildings require a good understanding of the local climate. Olgyay (1963) defines the comfort zone as a zone where humans can reduce the energy expended by the body in adapting to the surrounding environment. According to the 55-1992 ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) standard, thermal comfort is a state of mind that expresses satisfaction with the surrounding environment. That satisfaction is also influenced by environmentally responsive architectural design.

Microclimate is closely related to the personal needs and comfort of each individual. Several factors that often influence a microclimate in each room of a building are ventilation, building orientation, vegetation arrangement, and the use of building materials. (Imran, 2013), here is a simple illustration (Figure 1). (1) Ventilation/air exchange cycle. Wind and air enter for better ventilation from the front and sides of the building. Windows and openings should be operable on the north and south sides of the building to balance the microclimate. (2) Building orientation. Buildings should not face away from the prevailing winds in their surroundings. (3) Vegetation arrangement. In a planning context, vegetation is used to regulate circulation and microclimate (wind and sunlight). A tree on the west side of the building is better to grow tall, and a tree on the east side is better as a shrub. (4) Use of building materials. The building is made of strong and sturdy materials that can withstand wind and bad weather. (Imran, 2013)

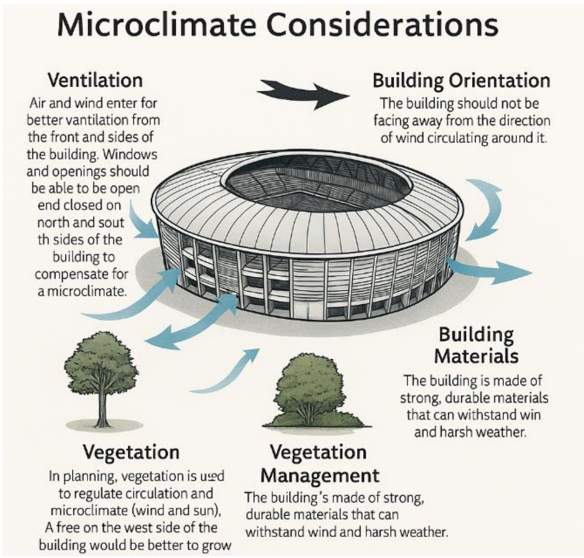

Figure 1. Basic Illustration Personal Requirements and Comfort are Closely Linked to the Microclimate.
(Source: Author Illustration, 2025)

This study aims to evaluate the influence of microclimate on architectural design to achieve comfort for users. This study also aims to provide an overview and insights into site locations situated in coastal areas, which need to be preserved for sustainability in the future. The function of this research also complements the literature that emphasises the microclimate, specifically the stadium building with a large capacity of up to 82,000 spectators. Since the JIS building's position and large massing provide the region its architectural face, the researcher is interested in using the JIS object as a case study that hasn't been done much by other researchers. Especially those that highlight the theme of microclimate as an important aspect during the planning stage of a building, which must consider natural elements, particularly wind speed, wind direction, sun direction, and air temperature. Consequently, this study makes a clear contribution to the field of architecture, especially in the area of ecological architecture, which builds on the findings of earlier research and is novel in this study.

METHODS

Figure 2. Study Location at Jakarta International Stadium (Source: Spatial Planning Agency, North Jakarta)

Location and Characteristics

The study location was conducted at the Jakarta International Stadium (JIS), North Jakarta, and serves as a stadium (Figure 2). JIS is located not far from the North Ancol Sea/Beach. The characteristics of coastal areas from a climatological perspective have local climate dynamics, including high winds, temperatures, and humidity. The existing land topography is a relatively flat area with a slope of 0 - 20% (on land, including the intertidal zone). Hydrologically, JIS is adjacent to a retention area, resulting in low water runoff, namely Lake Sunter and a river flanked by the Port Toll Road and R.E. Martadinata Road. In terms of land use, there is an intensive relationship between water and urban elements (edge). Geologically, JIS consists of soft soil. The presence of JIS near the port area also creates a transportation system and industrial zone. As a result of the activities in the surrounding area, several environmental issues have arisen, such as air pollution.

Data Analysis Method

Data analysis methods at JIS as a study location through observation, interviews, documentation, and literature (Sari & Bomo, 2022). Observation is conducted to generate information regarding architectural and landscape design. Through data collection, a descriptive approach was employed, focusing on survey techniques as the primary data source. The information comes from interviews conducted through direct field surveys to see the consistency of the obtained information with the existing facts. If inconsistencies are discovered, the data will be re-examined. The information gathered will not be used if an agreement cannot be reached. Experts in the fields of architecture and landscape design were interviewed. Documentation is another way to substantiate the accuracy of other fact-based material.

The cross-check stage is conducted between the literature and the conditions at the study site. The data collected consists of planning documents and images, as well as the design and construction results of JIS. The literature review comes from books, journals, articles, research reports such as theses, websites, and other sources that can be used for research purposes. Based on the literature, the components or elements that make up a building are parts that are interconnected with one another, forming a conceptual unity (Ching, 2007). All data that has been qualitatively analysed is then subjected to design development and subsequently becomes the stadium's design and construction. The result aims to provide an architectural design that offers comfort to stadium users and to understand the extent to which the microclimate in the surrounding environment influences the architectural design.

Data analysis is conducted with reference to comfort factors and site location characteristics, namely coastal/seaside areas. Site analysis aims to determine the responsiveness or adaptation to the environment, including wind, vegetation, and retention ponds (hydrology). Orientation analysis aims to determine the optimal direction for mass composition to achieve an environment that meets the required standards, including layout and vegetation. Analysis of the shape and design of buildings, in line with the development of science and technology, influences the formation of an internal environment within the building, which is a modification of the external environment, including mass composition and renewable energy. Analysis of the construction system and building materials influences the process of modifying the external environment's climate into a well-occupied internal environment, as well as the building materials. (Figure 3)

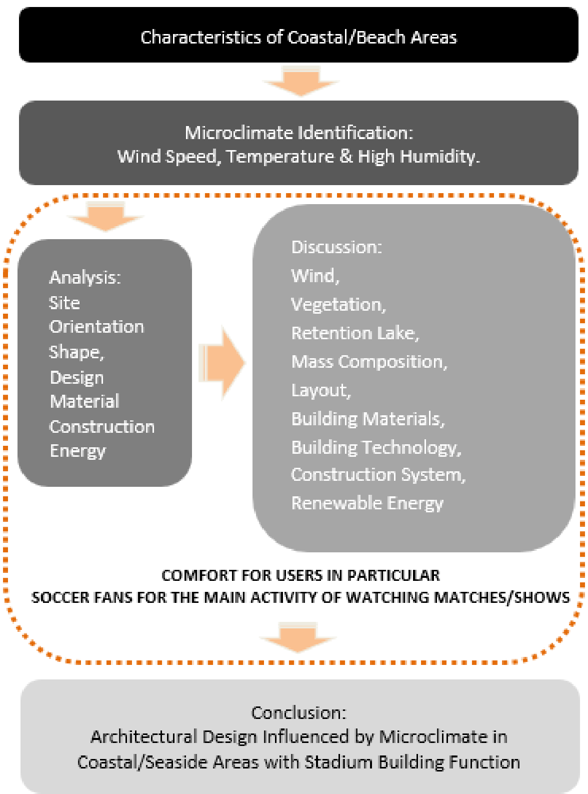

Figure 3. Framework of Research Mindset in Architectural Design in Coastal Areas
(Source: Author Documentation, 2024)

Comfort factors are also related to the need for space, circulation space, lighting, and air refreshment in the functional structure aspect. In the aspect of environmental structure, it consists of ecology, place, and time, while in the aspect of building structure, it consists of construction systems and construction techniques, and the structure of form consists of space and aesthetics. The aspect of building materials, which involves the appropriate and efficient use of building materials to produce high-quality buildings that are friendly to their surrounding environment. Environmental and climatic aspects that consist of lighting and colour, sunlight and building orientation, and wind and room ventilation. This refers to the research by Sari & Bomo (2022) on ecological architecture. Ecological architecture is the harmony between buildings and their surrounding nature, commonly referred to as environmentally conscious architecture (Muslim, Ashadi, & Anggana, 2018).

RESULTS AND DISCUSSION

Jakarta International Stadium is located approximately 400 metres from Ancol Carnival Beach, North Jakarta (Figure 4). The existence of JIS influences the design of JIS in terms of massing, specifically the shape and facade to address microclimate dynamics, particularly wind speed. In its planning, a "wind environment study" was conducted in Australia. The orientation of the JIS massing is east-west, known as the west ramp because it has a strategic point as the entrance pedestrian walk and the east ramp as the exit pedestrian walk. Just like the routes and accessibility for buses, cars, and bicycles, which have entrances and exits on the western part of the main JIS site. The western and eastern ramps are only used by pedestrians who use public transportation and are already integrated with the Trans Jakarta Bus Stop and Ancol Station.

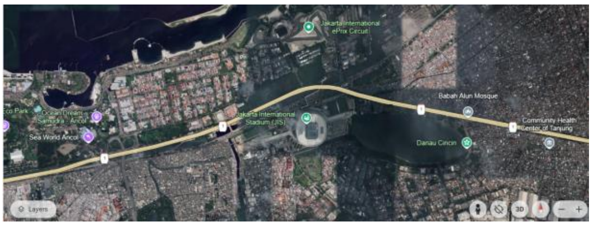

Figure 4. Visualisation of the JIS Building Aerial Map
(Source: JIS Project Document, 2023)

The main users of this stadium building are football spectators, namely supporters and others such as concert attendees or visitors from other events and the local community. The results of the "wind environment study" show that JIS has high wind speeds climatologically (Figure 5). From the image, it can be seen that high wind speeds are located in the west and north, while moderate wind speeds are in the east, and low wind speeds are in the south. The high wind speed is caused by the presence of Ancol Beach/Java Sea to the north and the west, where there are toll roads leading to arterial roads, serving as connecting roads to important locations/places, as well as local roads. With the results from the "wind environment study", planning and research are required to address the increased wind load that may be uncomfortable.

The discomfort factor for the large number of visitors is felt in the concourse (to the west), after the visitors enter by walking from the west ramp. Factors of discomfort experienced by visitors, such as reduced hearing (buzzing), strong winds causing intense blinking, and faster breathing. Activities in the concourse become the main focal point, not only as a meeting point and circulation path but also for enjoying views of the highway, river, and the Ancol Tourist Area in North Jakarta. This causes the human population to concentrate in the concourse (to the west). The solution is to implement a "wind screen pedestrian", which is vegetation (Figure 6). From the image, the layout of the vegetation as a windscreen in the western concourse on the northern side can be seen. This is also related to the shape of JIS, which extends from west to east, thereby achieving visitor comfort, especially during football events. This is also connected to JIS's long, west-east design, which guarantees visitor comfort, particularly during football games.

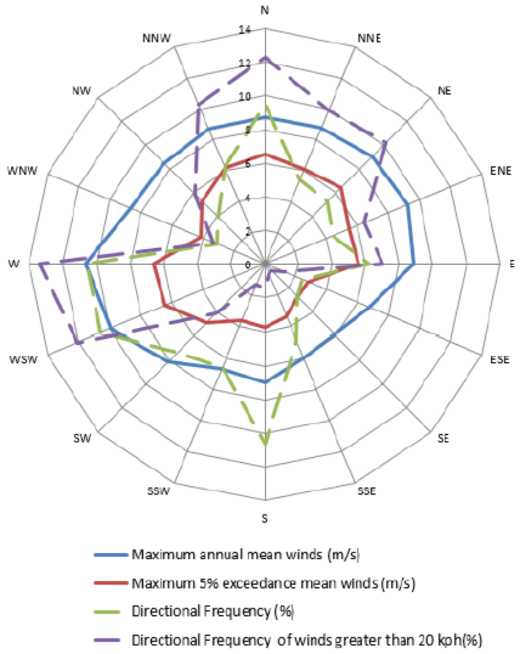

Figure 5. *Wind Environment Study* JIS
(Source: JIS Project Document, 2023)

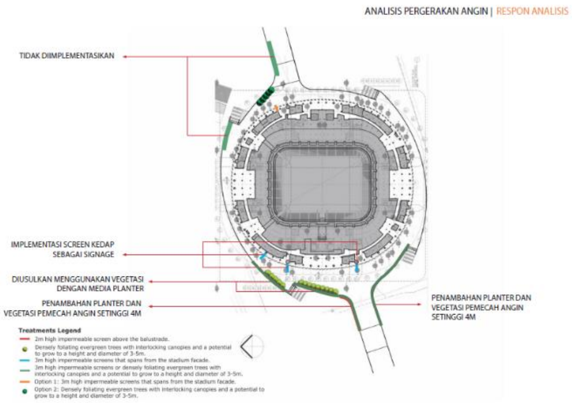

Figure 6. Vegetation as a Solution for Pedestrian Wind Screens
(Source: JIS Project Document, 2023)

The selected vegetation functions as a windbreak or wind controller. The types of vegetation are *Casuarina sp.* (Casuarina), *Syzygium oleana* (Pucuk Merah), *Podocarpus macrophyllus* (Lohansung), and *Chlorophytum comosum* (Lili Paris) (Figure 7). Its planting also involves a stratification level of various types of vegetation. The presence of vegetation is considered the most significant factor, where increasing the number of trees will enhance thermal comfort (Chan & Chau, 2021). This vegetation analysis refers to the guidelines for the provision and utilization of green open spaces in urban areas (Ministry of Public Works Regulation, 2008). The use of Casuarina trees (*Casuarina sp.*) is suitable for functions such as windbreaks and visual barriers. The characteristics of such vegetation are tall plants, shrubs/bushes; with dense leaf mass; planted in rows or forming a mass; and closely spaced planting < 3 m. Meanwhile, the lily plant serves as an example of a plant for shading roads and pedestrian paths (Ministry of Public Works Regulation, 2008).

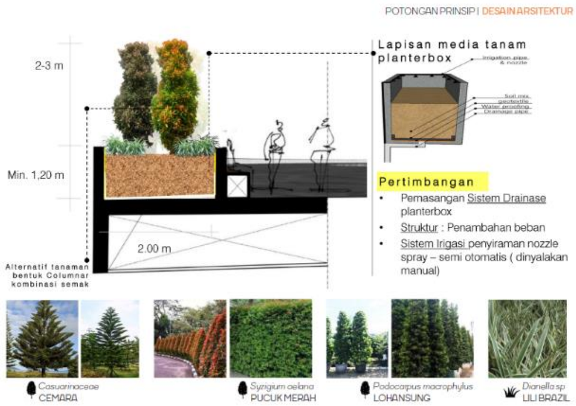

Figure 7. Type of Vegetation as a Wind Screen Solution
(Source: JIS Project Document, 2023)

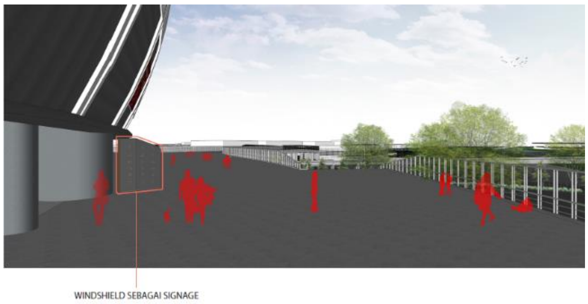

Figure 8. Signage Design as a Windbreaker
(Source: JIS Project Document, 2023)

The concept of environmentally conscious architecture adapts from the collaborative concept with nature by considering additional aspects in buildings to respond to the environment itself (Mahalalita & Krisdianto, 2017). A design that is appropriate and suitable for humans can help in responding to or interacting with the environment/site, creating a reciprocal relationship. At JIS, the orientation of the building does not turn its back on the prevailing winds in the surrounding environment. This is to optimise the number of gates and also the orientation of the sun. The eastern orientation optimises the eastern ramp as the exit gate and circulation for pedestrians. The architectural design to address excessive wind uses signage at the gate on the west side (Figure 8). The materials used for the signage are robust and resilient, able to endure severe weather conditions and high winds. The signage's windbreak design, sometimes referred to as a wind shield, is reinforced with sturdy materials.

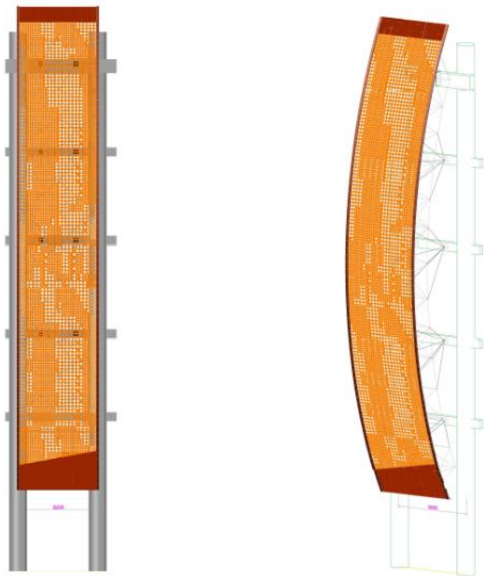

Figure 9. "A hole-hole design" as Air Circulation
(Source: JIS Project Document, 2023)

Figure 10. The Design of the JIS Facade Features a "Tiger" Motif
(Source: Author Documentation, 2024)

On the JIS facade, there is a perforated design that allows air circulation to enter and exit through different holes to maximize the comfort of supporters within the stadium building (Figure 9). The design of these holes is based on the philosophy of Betawi ornaments, specifically the gigi balang, which is derived from the traditional Betawi headband. The traditional Betawi headband has a unique circular fabric shape, which is then transformed into the design of the main stadium building, in the form of a dome, resembling an unbroken bowl with a circular base shape. Meanwhile, the binders are represented by the west and east ramps. The JIS facade will have perforations that from a distance appear to form a "Tiger" pattern (Figure 10). The small holes or perforations in the JIS design also serve aesthetic purposes as well as natural ventilation. This is a manifestation of fulfilling green building standards, as 50% of this component will allow natural airflow, especially for the stadium's grandstand (tribune) area.

The environmental aspect of lighting is evident in the mass composition of JIS. The holes in JIS have LEDs with a unique lighting design, especially at night (Figure 11). The design of the JIS building showcases technological performance with electrical fields. The lit LEDs can change, and the colours can vary. The construction of the JIS facade consists of panels arranged with joints. The JIS facade material has durability against salt content because the JIS location is about 400m from the beach.

Figure 11. Lighting System on the JIS Façade
(Source: Author Documentation, 2024)

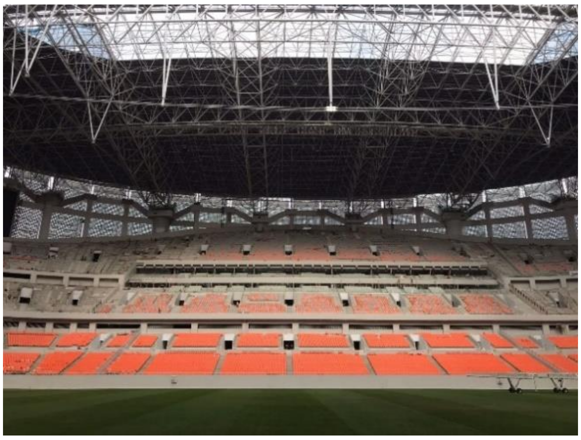

Figure 12. JIS Roof Frame Construction System with Parametric Design
(Source: Author Documentation, 2024)

Another construction system affected by the wind is the stadium roof frame (Figure 12). This is also related to the safety of the building. The roof frame is designed with a focus on calculations to withstand the roof load and other supports. The roof frame is also designed by incorporating mathematical rules or formulas (parameters) to enable the efficient creation of complex and flexible shapes. This parametric design is very suitable for the stadium roof structure, which is formed based on load distribution simulations, and it also creates aesthetic value in the JIS building.

Legal wood products are implemented on all new wood products; solid wood must have a legal wood validity statement with certificate evidence with ISO 14001 are used. The implementation of legal wood products is present in both the interior and landscape, with a weight value of 1 (one). The entirety of building materials is included in the basic design that regulates the outline specification of green building materials. Environmental science and advancements in building materials are interconnected in the effort to reduce global warming and improve air quality, in line with the GBCI's push (Sari & Bomo, 2023). Health-friendly materials include using low VOC (Volatile Organic Compound) paint, low mercury lamps, and non-urea formaldehyde composite wood (with laboratory evidence from the manufacturer). The use of emission-free materials and those resistant to moisture that produce spores and other microbes (GBCI, 2014). Such conditions are due to the location of JIS in the Ancol Beach area. Based on the North Jakarta City BPS (2024), the humidity in North Jakarta City is 85% - 95%, so the precise selection of building materials is applied to the architectural design at JIS, particularly the facade and roof.

On the JIS roof, ETFE (Ethylene Tetrafluoroethylene) is used as one of the building materials for the exterior panels. The reason for using ETFE is that it is much lighter than glass, does not easily get dirty or leave marks from fireworks, and has a lower environmental impact (greenhouse effect) (Widyakusuma, 2023). The advantage of ETFE is its flexibility to follow curved structures, and sunlight can enter even when the roof is closed. JIS, with its green building concept, allows the tribune area and the FOP field to receive sunlight even when the stadium roof is closed. At JIS, building technology is also applied to its roof, namely a retractable rooftop. This retractable roof serves the function of air circulation and natural ventilation to meet the O_2 (respiration) needs of the audience with a capacity of 82,000. On the other hand, the function of this retractable roof is also to capture sufficient sunlight, thereby minimising electricity usage, such as lighting. Thus, visitors can enjoy comfort from the architectural design.

The use of building materials at JIS also refers to green building and includes the Appropriate Site Development (ASD) criteria with the microclimate benchmark. The goal is to improve the microclimate quality around the building, which includes human comfort and the habitat surrounding the building. This comfort becomes the most important aspect because the stadium users, where the football spectator seats reach 82,000. The capacity of this football stadium affects the indoor climate, so the choice of material colour, namely the seats, is also related to ecology. The influence of the climate on humans can be examined in relation to the ecology that is consciously produced by the arising references. The combination of the colours of football supporters' seats, which are grey and orange or bright colours, affects the human ecological system and provides a sense of safety and reduces stress on humans and the environment related to their activities (Figure 13).

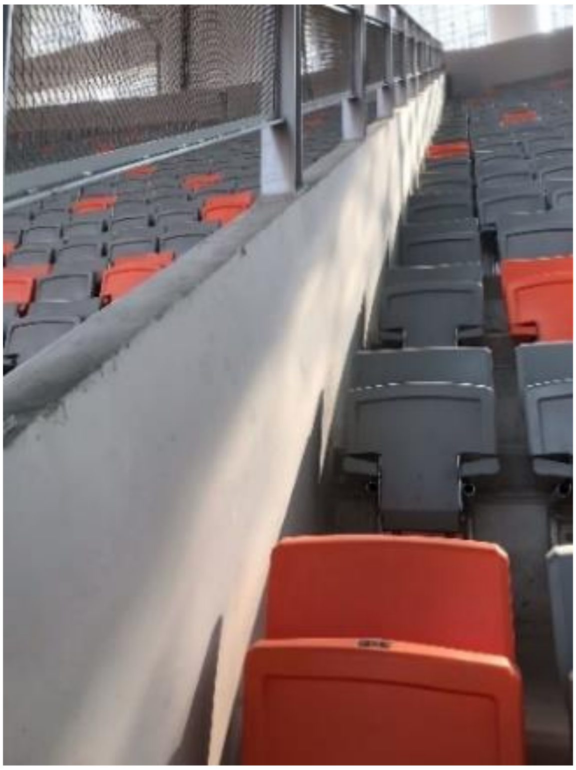

Figure 13. The JIS Stands' Seats' Colours
(Source: Author Documentation, 2024)

The presence of JIS, located in a coastal area, has the ability to reflect solar heat. To avoid the heat island effect, JIS uses various materials with a minimum albedo value of 0.3 on roof and non-roof pavements (Table 1). In the building roof area, it produces an albedo value (solar heat reflection power) of at least 0.3 according to calculations. JIS has 3 (three) roofed buildings, namely 1) Stadium, 2) MEP plant and TPS, and 3) Training Field Grandstand (Figure 14). In the non-roofed areas of the building, an albedo value (solar heat reflection power) of at least 0.3 is also achieved according to calculations. The pavement in the JIS area consists of roads, sidewalks/pedestrian ways, plazas, and concourses. The paving materials include andesite stone and concrete. The calculation for the albedo value of the roof pavement area is 0.65, while the albedo value of the non-roof pavement area is 0.40. Thus, the albedo values of the roofed and non-roofed pavement areas have a positive impact in reducing the heat island effect.

The choice of a colour approaching white for the roof and road pavement. The area pavement uses concrete and light-coloured andesite finishing. The roof uses natural-coloured aluminium sheet material, transparent ETFE, and PVDF (Polyvinylidene Fluoride). The colour of the material greatly influences the microclimate, where the use of lighter colours has a lower albedo value. The colour factor of the material also has an influence, as it affects the albedo properties, which in turn impacts the assessment of emissivity and ultimately leads to a high radiation temperature or surface temperature of the material (Lesi, 2017; Joo-Hwa & Lay, 2006). This heat can cause environmental surface temperatures to reach 40°C on paving materials such as concrete (Takebayashi & Kyogoku, 2018). To address this, JIS uses vegetation diversity. In Kartasapoetra (2006), it is explained that the microclimate conditions in vegetated environments are better compared to open fields.

Table 1. Calculation on Materials with a Minimum Albedo Value of 0.3 on Roof and Non-roof Pavements

Num.	Land Cover Types	Albedo Value (An)	Area, m² (Ln)	An x Ln
1	Snow White (ETFE)	0,65	15749,90	10237,44
2	Aluminum Zinc (Zincalum)	0,67	42982,62	28798,36
3	Concrete	0,35	805,88	282,06
4	Ash Grey (Metal Sheet)	0,47	1894,60	890,46
Acquisition of Albedo Values for the roof pavement area			40208,31 : 61433,00 = 0,65	
1	Light Gray Andesite Stone	0,47	15749,90	10237,44
2	Concrete Roads and Drainage Infrastructure	0,40	42982,62	28798,36
3	Concrete Plaza 1	0,40	805,88	282,06
4	Concrete Plaza 1A	0,40	1894,60	890,46
5	Concrete Plaza 2	0,40	1225,07	490,03
6	Concourse (elevated)	0,40	34837,75	13935,10
Acquisition of Albedo Values for Non-roof Pavement Areas			49.977,54 : 124.810,51 = 0,40	

The vegetation implemented at JIS functions as a buffer/screen, windbreak, and absorber of pollution, especially from vehicles. The presence of JIS in the coastal area, located in Tanjung Priok, has a wind speed of 5 knots (BPS North Jakarta, 2024). Meanwhile, JIS is also located at a strategic point that can be seen from the highway, where this road is frequently used by large vehicles, such as containers, large trucks, and others. In the softscape (soft elements) of the JIS landscape, mahogany trees (*Swietenia mahagoni*) are used as windbreak vegetation. Other vegetation that serves as air pollution absorbers in JIS includes Pothos (*Epipremnum aureum*), Japanese Jasmine (*Pseuderanthemum reticulatum*), and Wedelia (*Wedelia trilobata*), which are classified as shrubs.

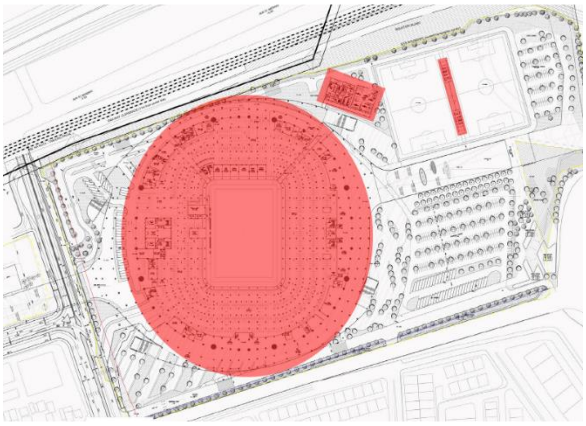

Figure 14. JIS has 3 (three) Roofed Buildings
(Source: JIS Project Document, 2023)

In the study by Hasim et al. (2015), the use of elephant grass (*Axonopus compressus*) functions as a microclimate controller and erosion control. According to Surjana & Ardiansyah (2013), the criteria for land use in green open spaces related to microclimate comfort include the placement of trees along main pedestrian paths to protect from solar radiation and strong winds and the use of materials with low albedo/solar heat reflection values. Meanwhile, the vegetation implemented in JIS functions as a buffer/screen, with climbing plants serving as barriers or physical boundaries, specifically Air Mata Pengantin (*Antigonon leptopus*). Thus, the presence of vegetation can support ecological architecture in the air and soil (earth). One of the principles of ecological architecture is adaptation to the local natural environment (Frick, 1998).

Plants in landscape design have three main functions: 1) architectural function, which is the use of plants to form vertical planes, especially in creating spaces; 2) environmental function, which emphasises the role of plants in creating comfort and safety from environmental disturbances, such as pollution, erosion, and others; and 3) aesthetic function of plants, which is to provide values of beauty (Handayani, 2009). The use of the Trembesi Tree (*Samanea saman*) is a large tree that has potential in green open spaces as an environmental identifier and has a canopy shape like an umbrella, thus possessing aesthetic value. In terms of architectural function, the Trembesi Tree (*Samanea saman*) has a semi-circular canopy shape, which aligns with the design of the JIS building. The presence of that tree can influence the environmental temperature and the standard air humidity for the human body between 40% and 40%-70%.

The use of vegetation in the study also refers to green building, which includes the Appropriate Site Development (ASD) criteria or Land Use Appropriateness with the benchmark of Site Landscaping. This vegetation analysis refers to the guidelines for the provision and utilisation of green open spaces in urban areas (2008), specifically coastal green open spaces. The selection of vegetation is prioritised from local areas that have adapted to conditions that have experienced seawater intrusion or are brackish and saline areas (Ministry of Public Works Regulation, 2008). In the softscape (soft elements) of the JIS landscape, the Mahogany Tree (*Swietenia mahagoni*) is used as vegetation suitable for the coastal green space. Meanwhile, the use of Casuarina trees (*Casuarina sp*.) is one example of plants for green belts that are resistant to waterlogging (Ministry of Public Works Regulation, 2008).

In designing effective sunlight lighting, there are five main strategies: shading, deflection, control, efficiency, and integration (Egan & Olgyay, 1983). The efficiency of natural lighting can be improved through the arrangement of building sites equipped with shady trees to minimise energy consumption (Sari & Bomo, 2022). Vegetation not only affects air circulation but also regulates the microclimate, such as sunlight intensity and wind direction (Thani et al., 2017). At the Jakarta International Stadium (JIS), the diversity of vegetation in the landscape is designed to address the extensive paved areas, and the presence of three retention ponds helps control humidity to meet health standards (40–50%). These retention lakes also serve as temperature-reducing elements, facilitating the natural airflow into the building through the facade while maintaining ecological balance and reducing heat radiation from hard surfaces (Lesi, 2017; Firly et al., 2019; Zahra et al., 2021).

Additionally, the utilisation of solar energy becomes a solution to meet electricity needs from renewable energy sources (Pandria & Prasanti, 2021). The high potential of solar radiation in Jakarta, especially in coastal areas, is utilised by using solar panels that convert solar energy into electricity (Pandria & Mawardi, 2021). The implementation of this system is divided into two models, namely solar park (on the ground surface) and rooftop photovoltaic system (on building rooftops) (Windarta et al., 2019). At JIS, the rooftop photovoltaic system concept is implemented by installing solar panels on the stadium roof, supporting energy efficiency while reinforcing the principles of sustainable design.

The use of solar panels is an architectural design adjustment to factors such as sun orientation, technological advancements, and changes in human life eras. Solar panels consist of 10 frames, each containing 60 modules, where each module has 300 WP (Figure 15). The total grid connection capacity of PLN JIS is 5,542.40 kVA, equivalent to 3,879.68 kW. The capacity of the west and east solar panels is 306 kWp. The percentage of solar panel power compared to PLN electricity is 306 kWp : 3879.68 kW, resulting in 7.89%. The use of solar panels in the study also refers to green building, which includes the criteria for Energy Efficiency and Conservation (EEC) with the benchmark of On-Site Renewable Energy. That benchmark contributes 5 (five) significant points because it has a very positive impact on electricity savings, such as FOP lighting. Achieving 5 points is the maximum point where every 0.5% of the stadium's electricity needs can be met by renewable energy sources.

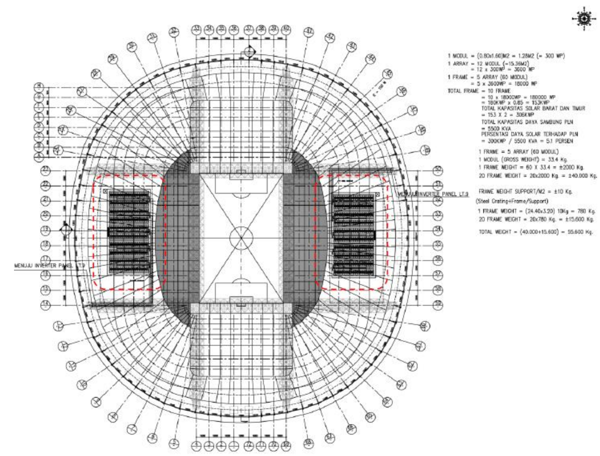

Figure 15. JIS has Solar Panels
(Source: JIS Project Document, 2023)

In the Environmentally Efficient Criteria (EEC), the Climate Change Impact benchmark aims to provide an understanding that excessive energy consumption can trigger climate change. The use of solar energy through solar panel technology has been proven to help reduce CO_2 emissions (Demeianto et al., 2021). These emissions are calculated based on the difference in energy needs between the designed building and the baseline building using the grid emission factor according to DNA Decision No. B/277/Dep.III/LH/01/2009. Simulations at JIS show CO_2 emissions reaching 2,298,516.78 kg/year (Project Document, 2023), and energy savings from the landscape design can have an impact comparable to or even greater than tree conservation. On the other hand, the vegetation in JIS also plays an important role in reducing air pollution, where large trees such as mahogany, trembesi, and banyan, as well as relocated trees like acacia, teak, and rambutan, are planted according to a landscape plan that considers geographical location and boundaries such as railway tracks and Sunter Lake.

JIS also implements eco-friendly material technology as part of its eco-architecture efforts. The building's facade uses Weathercoat paint, which is three times more resistant to extreme weather, high humidity, and UV rays, and is free of formaldehyde and low in Volatile Organic Compounds (VOCs), making it safe for the environment and the health of the occupants (Widyakusuma, 2023). This approach aligns with the principles of ecological architecture, which emphasises eco-design, taking into y6account the relationship between buildings and their surrounding climate to create comfort (Frick, 1998). Thus, the integration of renewable energy use, vegetation management, and the selection of environmentally friendly building materials at JIS are interconnected components in realising sustainable architecture that is responsive to climate change issues.

CONCLUSION

The JIS site is located close to Ancol Beach, so wind speed has a significant impact on the microclimate. The "wind environment study" at JIS shows that the placement of vegetation in the concourse (west ramp on the north side) functions to reduce wind speed, supporting outdoor space comfort. The orientation of the gate openings is evenly distributed on all sides of the stadium to optimise the capacity for up to 82,000 spectators. The mass of the JIS building is orientated west-east, with the western ramp serving as the main pedestrian entrance and the eastern ramp as the exit. The facade of JIS is designed with perforations, serving as natural ventilation while also showcasing typical Betawi ornaments. To support the microclimate and sustainability, local, recycled, and health-friendly materials such as legal wood products and those certified with ISO 14001 are used. The selection of land cover based on albedo values (roof 0.65 and non-roof 0.40) is effective in reducing the heat island effect, with a dominance of light colours such as grey. The stadium roof frame is designed to withstand wind and solar loads, using mathematical and algorithmic approaches for efficiency and aesthetics. The solar panel system with rooftop photovoltaic is also implemented to harness solar energy as part of the energy-saving strategy. Existing findings emphasise that the arrangement of openings and passive ventilation adaptive to the prevailing wind direction can reduce reliance on active cooling systems in open-air stadiums. These findings reinforce the approach of passive design and the use of vegetation as applied in JIS as a microclimate-based solution.

REFERENCES

ASHRAE, 2017. ASHRAE Handbook Fundamentals. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Inc.

Badan Pusat Statistik. (2024). *Kota Jakarta Utara dalam Angka 2024.* Jakarta: Badan Pusat Statistik Kota Jakarta Utara.

Brown, R. D., Gillespie, T. J. (1995). *Microclimatic Landscape Design: Creating Thermal Comfort and Energy.* Canada: John Wiley and Sons, Inc.

Chan, S. Y., Chau, C. K. (2021). On the Study of the Effects of Microclimate and Park and surrounding Building Configuration on Thermal Comfort in Urban Parks. *Sustainable Cities and Society*, 64.

Ching, F. D. (2007). *Architecture: Form, Space, and Order*. Jakarta: Erlangga.

Demeianto, B., Yaqin, R. I., Arkham, M. N., Imawan, B., Bastian, K., & Mulyani, I. (2021). Edukasi Teknologi Panel Surya sebagai Sumber Energi Listrik Aquaponik di Kelurahan Tanjung Palas Kota Dumai. *Jurnal Ilmiah Pengabdian Kepada Masyarakat Al Khidmat* Vol.4(2), 86-93.

Dokumen Proyek Manajeman Konstruksi Jakarta International Stadium. (2023). Arsitektur, Struktur, Lanskap, Mekanikal-Elektrikal. Jakarta.

Egan, D. M., Olgyay, V. W. (1983). *Architectural Lighting*: Second Edition. New York, USA: Mc. Graw Hill Publication Company.

Firly, K., Setyaningsih, W., & Suparno. (2019). Penerapan Ekologi Arsitektur pada Pengembangan Kawasan Desa Wisata Dukuh Kajongan Kota Tegal. *Jurnal Senthong* Vol.2, 21-30.

Frick, H. (1998). *Dasar-dasar Eko-Arsitektur*. Yogyakarta: Kanisius.

Frick, H., Darmawan, A. (2007). *Ilmu Fisika Bangunan*. Yogyakarta: Kanisius.

Green Building Council Indonesia. (2014). Greenship Rating Tools for Home version 1.0.

Handayani. (2009). Arsitektur Lanskap. Modul Kuliah Arsitektur UPI, Jakarta.

Hasim, I. S., Rizqan, B. S., Darel, R. P. L. P., & Abiel, F. A. (2015). Rancangan Elemen, Sistem Sirkulasi, dan Tata Hijau Lanskap Pada Lahan Kontur di Hotel Padma Bandung. *Jurnal Reka Karsa* Vol.1(3), 1-12.

Imran, M. D. K. (2013). Pengaruh Iklim Terhadap Bentuk dan Bahan Arsitektur Bangunan. *Jurnal Peradaban Sains, Rekayasa dan Teknologi RADIAL.*

Joo-Hwa, B., Lay, O. B. (2006). *Tropical Sustainable Architecture. Social and Environmental Dimensions*. London: Architectural Press.

Karyono, T. H. (2010). *Green Architecture: Pengantar Pemahaman Arsitektur Hijau di Indonesia.* Jakarta: Rajawali Press.

Lakitan, B. (2002). *Dasar-dasar Klimatologi.* Jakarta: Raja Grafindo Persada.

Lesi, M. (2017). Iklim Mikro di Sekitar Permukaan Air. Pascasarjana Institut Pertanian Bogor.

Lippsmeier, G., (1994). *Bangunan Tropis.* Jakarta: Erlangga.

Mahalalita, R., Krisdianto, J. (2017). Sistem Arsitektur Berwawasan Lingkungan. *Jurnal Sains dan Seni Pomits* Vol.6(2), 2337-3520.

Margaretha, P. (2007). Studi Hubungan Antara Kondisi Iklim Mikro dan Persepsi Pengunjung Terhadap Kenyamanan Termal (Studi Kasus di TMI, Jakarta). Fakultas Pertanian IPB: Bogor.

Ministry of Health Indonesia about Housing Health Requirements 829/MENKES/SK/VII/1999.

Ministry of Public Works Regulation about Guidelines for the Provision and Utilization of Green Open Spaces in Urban Areas 05/PRT/M/2008.

Muslim, A. A., Ashadi, & Fitri, A. S. (2018). Konsep Arsitektur Ekologi pada Penataan Kawasan Wisata Candi Cangkuang di Garut, Jawa Barat. *Jurnal Arsitektur Purwarupa* Vol.2, 57-70.

Nolasari, A. B., Toyyibah W., Kurniawan, A., Rembulan, D. W. S., Chandra, M. F. W., & Koerniawan M. D. (2023). Analisis Iklim Mikro Kawasan Berdasarkan Kerapatan Bangunan dan Vegetasi di Kawasan ITB Kampus Ganesha Bagian Selatan. *Jurnal Reksabumi* Vol.2(2), 75-86.

Olgyay, V. (1963). *Design with Climate: Bioclimatic Approach to Architectural Regionalism.* Princetown: Princetown University Press.

Pandria, T. M. A., Mawardi, E. (2021). Penentuan Sudut Kemiringan Optimum Berdasarkan Energi Keluaran Panel Surya. *Jurnal Optimalisasi* Vol.3(5), 123.

Pandria, T. M. A., Prasanti, A. N. (2021). Penerapan Panel Surya sebagai Sumber Energi Listrik Alternatif pada Gedung Fakultas Teknik Universitas Teuku Umar. *Jurnal Serambi Engineering* Vol.6(4), 2320-2329.

Sari, P., Bomo, D. P. (2022). Desain Wayfinding dalam Keterbacaan dan Pelaksanaan Studi Kasus Jakarta International Stadium. *Jurnal Ilmiah Arsitektur UNSIQ* Vol.12(2), 116-130.

Sari, P., Bomo, D. P. (2023). Kajian Prinsip Arsitektur Ekologi pada Rumah Tinggal di Daerah Panorama Bandung. *Jurnal Arsitektur SINEKTIKA* Vol.20(2), 120-134.

Sudibyo, S. (1987). Media Teknik Edisi Nomor 2 Tahun IX.

Surjana, T. S., & Ardiansyah, A. (2013). Perancangan Arsitektur Ramah Lingkungan: Pencapaian Rating Greenship GBCI. *Jurnal Arsitektur Universitas Bandar Lampung* Vol.2(3), 1-14.

Takebayashi, H., Kyogoku, S. (2018). Thermal Environmental Design in Outdoor Space Focusing on Radiation Environment Influenced by Ground Cover Material and Solar Shading, through the Examination on the Redevelopment Buildings in Front of Central Osaka Station. Japan. *MDPI Sustainability Jurnal*.

Thani, S. K. S. O., dkk. (2013). Outdoor Thermal Comfort: the Effects of Urban Landscape Morphology on Microclimatic Conditions in a hot-humid city. *WIT Transactions on Ecology and The Environment* Vol.179.

Widyakusuma, A. (2023). Prinsip *Green Building* Jakarta International Stadium untuk Arsitektur Kota Jakarta yang Berkelanjutan. *Jurnal Trave* Vol.27(2), 66-79.

Windarta, J. E., Sinuraya, W., Abidin, A. Z., Setyawan, A. E., & Angghika. (2019). Perancangan Pembangkit Listrik Tenaga Surya (PLTS) Berbasis Homer di SMA Negeri 6 Surakarta sebagai Sekolah Hemat Energi dan Ramah Lingkungan. *Prosiding Seminar Nasasional MIPA* Universitas Tidar, pp. 21-36.

Zahra, Sangkertadi, & Kumurur, V. (2021). Pengaruh Material Lansekap terhadap Perubahan Iklim Mikro di Kota Tropis Lembab dengan Studi Kasus di Kawasan Pantai Kota Manado. *Jurnal Arsitektur Pawon* Vol.5(2), 169-184.