Evaluation of the Phinisi Tower Building at Makassar State University from an Ecological Architecture Perspective

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Abstract

Tropical environments, characterized by high heat and moisture levels, necessitate an innovative approach to building construction and design. Drawing upon empirical evidence from a focused case study on the Phinisi Tower at Makassar State University (UNM), we argue that the strategic incorporation of Brise Soleil and Second Skin significantly impacts occupant comfort and the building's ecological sustainability.

This study aims to evaluate the Phinisi Tower at Makassar State University based on Olgyay's bioclimatic theory. The focus of the evaluation centers on the building's form, explicitly analyzing its solar shading, airflow, and temperature balance within the spaces. The overarching goal is to assess the ecological performance of the building.

To address these issues, the research analyses the architectural form of the Phinisi Tower. The methodology involves visualization techniques through simulation, examining various architectural components that constitute the building's form. Noteworthy architectural elements in the Phinisi Tower include using brise soleil and second skin on its facade, its semi-outdoor stilt structure at the base, and the segregated building masses. Analytical tools such as Covetool, Autodesk Forma, and Ecotect scrutinize each building component through performance indicators.

Utilizing a blend of empirical evidence, measurements, simulations, and case studies, we found that Brise Soleil is an effective passive solar shading mechanism, significantly reducing heat and light penetration. Concurrently, the Second Skin is an additional thermal barrier, aiding temperature regulation and energy efficiency. Furthermore, the segregated masses of the building successfully channel wind through the gaps. At the same time, the open space at the base of the structure effectively elevates the building, allowing for better air circulation.

Keywords: Tropical environment, Ecological performance, Building form, Solar shading, Air flow, Temperature balance, Brise soleil, Second skin

Introduction

Economic development often leads to the utilization of natural resources. As the environment progressively deteriorates, communities are feeling its impacts. According to the United Nations Environment Programme (UNEP, 2019), buildings contribute nearly 40% of the global greenhouse gas emissions. This statement aligns with the Paris Climate Agreement's targets to reduce greenhouse gas (GHG) emissions by 2030. As integral parts of urban environments, buildings influence ecological health considerably, making their design a critical factor in environmental mitigation.

Architectural morphology significantly affects energy usage, influencing local microclimates and the broader environmental impact (Shareef, 2020). The Phinisi building boasts distinctive features, such as its elevated base structure. Sing Yu, the architect behind this project, elucidated in his 2000 blog post that this design is an adaptation of traditional stilt houses, aiming to instill a sense of spaciousness and comfort. Thus, the traditional architectural style of Phinisi Makassar not only retains historical and cultural significance and integrates modern adaptations. Contemporary design merges these traditional elements with advanced technology to enhance the comfort levels of the occupants.

In order to manage excessive light, structures incorporate shading devices like horizontal overhangs (brise-soleils), inner or outer glazing shades, or roller blinds. These serve as passive cooling mechanisms, safeguarding interior environments from excessive heat (Dudzińska, 2021). The design of Menara Phinisi UNM extensively incorporates shading devices, such as overhangs, lattices, and brise soleil. These devices reduce direct sunlight penetration, decreasing the need for artificial cooling.

Research on ecological architectural principles in building forms and elements has been extensive. Design elements, such as building orientation and shape, can be adapted to suit the local climate, enhancing energy conservation. By carefully selecting the design and orientation, reliance on artificial lighting, heating, and cooling can be curtailed, which diminishes energy consumption and augments overall efficiency (Haseeb et al., 2023). Effective shading strategies and improved city wind flow are pivotal to thermal comfort in hot and arid urban areas (Aghakarimi et al., 2023). The climatic zone where studies on urban form and environment are conducted plays a pivotal role in drawing accurate conclusions. Additionally, the scale of the constructed environment is a critical factor (Ratti et al., 2003). An analysis from the southern and northern perspectives is vital to comprehend the effects of brise soleil and blind shading mechanisms on fully-glazed facades (Al & Ouahrani, 2017).

Building morphology stands out in architectural deliberations as a crucial component that can be finetuned to align with regional climatic conditions, aiming at optimal energy conservation. Thoughtful configuration choices can substantially lessen the dependency on artificial energy sources, resulting in decreased energy footprints and elevated operational efficiency. A recurrent theme in many research undertakings is that understanding ecological and environmental techniques requires a comprehensive exploration of building morphologies and specific architectural components, including elements like the brise soleil.

This research explores architectural sustainability by focusing on the Phinisi Tower, a hallmark of contemporary design in Makassar. The study seeks to understand how the tower's unique shape and design principles contribute to its sustainability metrics. The evaluation centers on the building's form, explicitly analyzing its solar shading, airflow, and temperature balance within the spaces. The details for this research will primarily focus on examining the Phinisi Tower in terms of three critical aspects of ecological sustainability: 1) The building form employed for effective solar shading, 2) the interplay between building form and wind dynamics, 3) the correlation between building shape and temperature comfort standard. By sustaining a narrowed research scope, the aim is to provide an in-depth dissection of the Phinisi Tower's eco-friendly design facets, underscoring the revolutionary capabilities of architectural forms in bolstering ecological sustainability, thereby rendering structures energy-efficient, comfortable, and enduringly sustainable.

Theoretical Foundations

Ecological thinking emphasizes the dialectical unity between natural and artificial environments, showing reverence for what already exists and maintaining an openness to other perspectives (Couvelas, 2019). Architectural ecology is a building philosophy that underscores the harmony between the natural environment and human-made structures. It considers the primary constituents: humans, buildings, and the environment. The diverse cultural backgrounds of humans enable them to manage both structures and the environment in harmony. Architectural ecology is a design philosophy that aims to establish a system that preserves environmental symbiosis within a structure or area without disrupting natural cycles (Yuliani, 2012).

Ecological design facilitates reducing energy and material flows so that human communities can be deeply re-integrated into the surrounding ecological communities. For instance, if heating a house requires excessive electricity or natural gas, it is possible to harness passive solar heating through careful building orientation and the appropriate selection of building materials. Similarly, every environmental impact can stimulate innovative ecological design (Van & Cowan, 2007). In his book, "The Technology of Ecological Building", engineer Klaus Daniels, as cited by Peters (2011), expounds on the principles of ecological construction. These include the need for detailed site studies, an analysis of building form and orientation, and consideration of local climatic conditions. His approach revolves around optimization, integrating building systems, and merging technological solutions with passive systems to enhance performance (Peters, 2011).

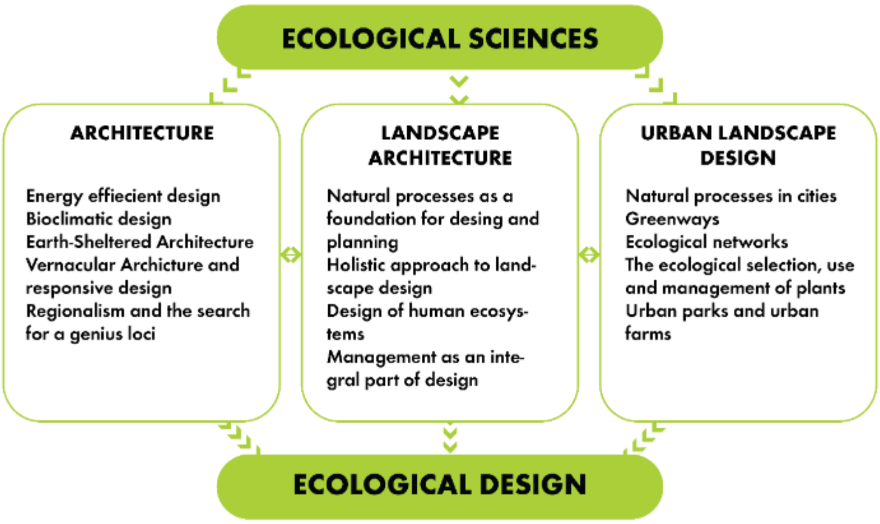


Fig. 1: Ecology in architecture, landscape, and urban landscape
Source: Makhzuomi and Pungetti, 2005

The earlier chart illustrates that the bioclimatic design falls within ecological science. There are six bioclimatic ecology principles, as Olgyay mentions: site selection, orientation, shadow calculation, building shape, airflow, and temperature balance. Of these six factors, the site selection and orientation analysis are excluded from evaluating the ecological concept since the building has already been established. These factors can be set aside. The main focus of the researcher is on the building shape viewed from the aspects of building shadow, airflow, and temperature balance, which will be the variables in this study. Concerning the shape aspect, the application of a building's ecological aspect can be analyzed through its constituent elements. The following are theories, according to Olgyay (2015):

1) Building Form: The form of houses and buildings should be consistent with beneficial or detrimental thermal environmental impacts; hence, certain shapes are preferred over others in specific environments.

2) Shadow Performance: Shading calculations are based on the axiom that throughout the year, during scorching times, the sun should strike the building, and during peak heat, the structure should be shaded. Sun path charts, combined with geometric and radiation calculations, can elucidate the effectiveness of shading devices.
3) Airflow: Air movement can be categorized into wind and breezes based on intensity. Winds during excessively hot periods should be intercepted, while cool breezes should be utilized during extreme heat. Indoor air movement should meet bioclimatic needs. Calculations based on airflow rates through the building combined with flow patterns can determine openings' location, configuration, and size.
4) Temperature Balance: Careful material usage can achieve a certain degree of balance. The materials' lag time and insulation characteristics can be employed for improved indoor conditions. Heliothermic planning, grounded in heat flow studies, provides quantitative measures for the relative importance of building elements. The balance criteria are minimal heat flow out of the building in winter and minimal heat gain in the structure during excessive heating periods.

This research type involves utilizing computer simulations. Computer graphics software offers a platform where architectural models can be crafted to convey the fundamental elements of architectural composition effectively. With its ability to handle complex design operations, including symmetry, scaling, substitutions, and parametric and geometric modifications, computers can employ analysis to simulate design creation. This analytical reconstruction of elemental vocabularies and creation processes provides profound insights into architectural design. When employing computers, these depictions' representations and underlying principles become a rigorously formalized understanding (Oxman, 2000).

The Case Study

(a) (b)

Fig. 2: (a) Phinisi UNM front façade perspective (b) Courtyard of Phinisi UNM
Source: Author, 2023

The Phinisi Tower transcends architectural brilliance; it symbolizes cultural conservation, intertwining Makassar's deep-seated history with modern architectural nuances. The visionary behind this edifice, architect Yu Sing, passionately discusses the significance of melding traditional ethos, heritage, and architecture with current design paradigms on his blog. He contends that the enduring principles of vernacular architecture are vast reservoirs for contemporary inspiration. Translating these native insights and principles to today's scenario is pivotal in safeguarding and magnifying the area's cultural assets (Sing, Yu, 2009).

Each design decision in the tower, from its overall form to the intricate details, is rooted in this local wisdom, especially in ecological manners. In the design of Phinisi UNM, passive design elements, notably the inclusion of brise soleil and a secondary skin, are prominently integrated. It is imperative to assess these features' efficacy and environmental sustainability quantitatively. Furthermore, the building's elevated or 'stilted' form on the first level has been strategically implemented to harness wind currents, promoting thermal comfort within this space. Preliminary observations suggest that such a building configuration possesses the potential to induce a reduction in ambient temperatures on the said level. Further simulations are warranted to validate these hypotheses in the context of sustainable architectural practices.

Literature Review

Research on ecology in the context of buildings is a concept that many scholars have explored in the past. However, even if centered on similar topics, each study possesses unique scopes, subjects, and methodologies. Here are various studies on ecological design, each showcasing diverse approaches from different authors:

1) Diana et al. (2020) have explored the incorporation of bioclimatic architectural principles in the Novotel Suite Surabaya. The study employed a descriptive qualitative method combined with empirical research for analysis. Drawing upon nine of Ken Yeang's theories on bioclimatic architecture, the case study of Novotel Surabaya was assessed based on a singular variable with the following indicators: building core positioning, orientation, windows and openings, balconies, use of transitional spaces, building protection, relation to landscape, passive shading, and floor insulation. The findings suggest that while all nine indicators were primarily met, the heat barriers in the Novotel's floors did not cover the entire hotel structure. However, special attention was given to specific sides of the building.
2) Setiawan (2018) has investigated the application of ecological and green architectural theories in the design of a house, specifically the Omah Harimurti project in South Jakarta. This research critically analyzed the design principles presented by Sim Van Der Ryn, Stuart Cowan, Robert, and Brenda Vale and how they were manifested in the Omah Harimurti project. By juxtaposing their design philosophies, the study delineated four pivotal criteria for ecological-green architecture: the paramount importance of nature in design, addressing site-specific challenges, seeking environmental solutions throughout the design process, and emphasizing climate sensitivity with a focus on energy conservation. Based on these standards, the study concluded that the Omah Harimurti aligns with ecological and green architecture principles.
3) Mari et al. (2019) have examined the impact of vegetation brise soleil on the thermal environment of residential structures in hot and humid tropical climates. The study contrasted two cases: buildings incorporating vegetation in their shading elements and those devoid. The methodology involved measuring indoor and outdoor temperatures for both scenarios. The findings revealed a notably lower indoor temperature in a building with vegetation shading than the other. This research underscores the conclusion that vegetation shading, as a passive cooling element, can enhance the thermal environment and promote energy efficiency in buildings.
4) Faharuddin (2016) has investigated the effectiveness of the Phinisi Tower's design on wind speed patterns and air circulation in both the tower and its nearby environment. The research employs a combination of direct measurements using an anemometer and computer simulations via Vasari Beta 3 software. The simulations involve comparing different tower designs to examine the Phinisi Tower's effectiveness in influencing wind speed and air circulation patterns in its surrounding area. The study's findings indicate that the Phinisi Tower's design is highly effective in mitigating wind speeds, with simulation results ranging from 0.98 to 2.95 m/s in the

adjacent environment. These results meet the Beaufort scale comfort standard of 1.6 ± 3.3 m/s, indicating a positive impact on human comfort.

The studies above offer a comprehensive perspective on ecological architecture in various settings, ranging from residential buildings in metropolitan cities to real estate. Each study utilizes diverse methodologies, such as simulation-based analysis, qualitative descriptive and comparative analysis, and different theoretical foundations like Ken Yeang's principles, Sim Van Der Ryn, and Stuart Cowan's ideologies. They address various ecological concerns, from climate-adaptive designs and bioclimatic architecture concepts to green architectural principles.

In summary, while the existing research papers provide valuable contributions to ecological architecture, the forthcoming study on Phinisi UNM in Makassar distinguishes itself through its methodology, theoretical underpinnings, and focus on specialized design elements. Although the planned research shares some similarities with Faharuddin's 2016 study, particularly in location, it diverges significantly in scope and focus. This research is grounded in Olgyay's ecological theory and looks at how building forms adapt to their surrounding environments, specifically in terms of solar shading, airflow, and indoor temperature balance. This comprehensive approach allows the research to delve into multiple dimensions of building design, extending beyond wind speed and air circulation to include solar shading and temperature balance. The research aims to fill an existing knowledge gap by evaluating the effectiveness of specific passive design strategies in office buildings in tropical climates like Makassar.

Research Methods

The research methodology employed in this study combines both survey techniques and digital software tools. Direct field observations were carried out, with the researcher's focus on the building form's response to three specific variables. Digital software, or exploratory data, was used to compare these variables.

Collecting Data

a) **Site Visit:** During the site visit to Phinisi UNM, data was gathered, including the building's existing drawings, which were essential for creating a 3D model.
b) **Measuring:** Measurements were conducted using specialized tools: the UNI-T UT333 for assessing temperature and humidity and the Anemometer GM 816 for determining wind velocity. This data collection spanned from mid-July to mid-August and was conducted on weekdays. Hourly recordings of temperature, humidity, and wind speed were taken over several hours to determine the average performance of the building.
c) **Documentation:** Capturing and sketching detailed photographs of various architectural features and annotating specific nuances observed on-site.
d) **Interview:** An open-ended interview was organized with the management of Phinisi UNM. The crux of this interaction was to glean insights into the building's design, particularly emphasizing its ecological and environmental performance.

The Simulation

The study focused on simulating shading using the Solar Tool Ecotect software to analyze light filtering on windows from all four cardinal directions (north, south, east, and west). Leveraging its advanced shading analysis capabilities, this software enables architects and designers to maximize the use of natural light, minimize excessive heating, and enhance the energy efficiency of buildings. A secondary shading experiment was conducted using the Forma application by Autodesk to understand the building's shadow simulation further. The simulation inputs included the winter solstice date, June 22, and the summer solstice, December 22, for the Southern Hemisphere.

Airflow or wind analysis was conducted using the Forma application, incorporating directly imported 3D designs. Forma primarily simulates 3D objects and cannot analyze wind movement with the addition of elements like vegetation. Additionally, this software can determine wind standards within the building's surrounding area. The established criteria classify wind standards: sitting, standing, strolling, walking, and uncomfortable. Within the software, the simulation quantifies the percentage of wind from each direction and models how the building's shape would respond to wind exposure from various angles.

Temperature balance analysis was conducted using the Covetool software to measure the SDA (Sustainable Design Assessment) and ASE (Annual Sunlight Exposure) values based on the LEED standard v4.0 - IEQ c7 Daylight and "IES LM-83". Ecotect is another software utilized for assessing temperature balance, which simulates one level of the building to determine the significance of sun-shading devices. The evaluations carried out include the mean radiant temperature and solar access analysis.Here are the limitations and capabilities of each software utilized for this research:

Table 1: Comparison of capabilities and limitations of each simulation software
Source: Author, 2023

No.	Types of Software and Their Uses	Capabilities	Limitations
1.	Ecotect • Used to analyze temperature balance	• Can analyze continuously over time. • Extensive simulation options ranging from lighting, thermal, acoustics, visuals, wind, and more through plugins. • Detailed temperature analysis with a complete grid mode, including indicators and temperature readings. • Ability to view the solar path directly within the software	• The software responds very slowly when used for comprehensive building analysis. • Zoning illustrations can only depict perpendicular layouts. • Imported buildings do not automatically detect zones. • Overlapping objects or lines can lead to errors during analysis. • It's preferable to perform the modelling directly within the software. • Unable to analyze outdoor surface temperatures.
2.	Solar Tool Ecotect • Used to analyze solar shading	• Used to analyze the percentage of light entering through window surfaces. • Analysis includes both graphical models and presentation tables. • Capable of analyzing from any direction or angle. • Fast in generating both calculation and modelling results.	• Limited in its modelling capabilities; can only analyze vertical and horizontal window models. • Cannot analyze imported models.
3.	Autodesk Forma • Used to analyze solar shading • Used to analyze wind speed and direction	• Wind speed analysis results are indicated by color and wind velocity. • Shadow analysis results are represented by color and duration of exposure. • Wind speed analysis results are indicated by color and wind velocity.	• Cannot display specific temperature degrees; only indicators and overall percentages are available. • Wind depiction is only in image form; no animations are provided. • Analysis is limited to shape and does not include materials. • There is a time delay for simulation results.

No.	Types of Software and Their Uses	Capabilities	Limitations
		• Easy to import objects for analysis. • The User Interface is very user-friendly. • More realistic in depicting locations compared to other applications. • Pre-existing views of surrounding building layouts and locations are available. • No need to install the software. • Automated in terms of analysis; no data input is required, just the selection of building placement location.	• Unable to analyze the interior portions of a building.
4.	Cove.tool • Used to analyze temperature balance	• Analysis can determine ASE, shading, radiation, visual quality, COVID occupancy rating scores, and contextual studies of locations in 3D visualization. • No need to install the software. • Pre-existing views of surrounding building layouts and locations are available. • Automated in terms of analysis; no data input is required, just the selection of building placement location.	• Extended duration needed for analyzing buildings. • An additional extension is needed to install on SketchUp or Revit for importing buildings into the project. • Manual sorting of building components such as floors, walls, and furniture is required. • The shadow analysis is not very detailed.

Both shading and temperature balance evaluations were conducted using two models: one with the current building's shading device and another without a shading device or with a modified solar shading device. The goal was to discern the significant differences between the two models and the efficiency of building devices in reducing direct sunlight that could lead to occupant discomfort.

The Research Steps

a) **Site Visits:** Gather data from authorized personnel at Phinisi UNM, including as-built drawings of Phinisi UNM.

b) **Measurements:** Assess five location points on the ground floor of the Phinisi building, recording wind, temperature, and humidity using specified tools.

Fig. 3: Measurement Point
Source: Google Earth, 2023

Zone 1: Entrance
Zone 2: Center
Zone 3: Cafetaria
Zone 4: Pond, Courtyard
Zone 5: Northside

c) **Standards Acquisition:** Obtain thermal comfort standards, focusing on temperature per SNI 03-6572-2001, humidity Bauer et al., indicator, and wind velocity standards according to Frick.
d) **Data Collection:** Record information from informants and visitors at Phinisi UNM to understand the site's application of ecological architectural principles.
e) **3D Modeling:** Construct a 3D model of the building using documentation and as-built drawings to mirror the existing structure accurately.
f) **Model Modification:** Adjust the model by removing solar shading devices to analyze differences compared to Phinisi's current state.
g) **Comparison:** Following each model modification and simulation outcome, compare measurements to established standards to determine compliance.

Findings

Solar Shading Analysis

Curtain walls on floors 4-17 of the building can cause discomfort. Shading calculations are needed to avoid solar heat. Shading will be measured using a Solar Tool to determine how much coverage the building shading device has at Phinisi Tower. It is used by calculating how many percent of light will enter the building through the table as the measurement.

First of all, the size of the wall to be simulated is 8 meters with a height of 3.5 meters. North offside or slope from the north is set at -2.9. There are three horizontal shading and two vertical shading with a width of 1.1 meters and the same size as the walls and windows that will be simulated at 8 meters.

1) Analysis of Building Shade Mechanisms

Below is the table for June 22 or the percentage of shading that operates on the north side of the building. The selection of the month is due to the winter solstice on the south side of the Earth, an astronomical event that occurs when the Earth's North Pole is tilted at its maximum angle (about 23.5 degrees) towards the Sun.

Table 2: Daily percentage horizontal shading of north side
Source: Author, 2023

Tabulated Daily Solar Data

Latitude: -5.2°
Longitude: 119.5°
Timezone: 120.0° [+8.0hrs]
Orientation: -2.9°

Date: 22nd June
Julian Date: 173
Sunrise: 06:12
Sunset: 17:54

Local Correction: -3.8 mins
Equation of Time: -1.8 mins
Declination: 23.4°

Local	(Solar)	Aziumuth	Altitude	HSA	VSA	Shading
06:30	(06:26)	66.0°	3.9°	68.9°	10.8°	37%
07:00	(06:56)	64.9°	10.7°	67.8°	26.6°	67%
07:30	(07:26)	63.4°	17.4°	66.3°	38.0°	82%
08:00	(07:56)	61.4°	24.1°	64.3°	45.9°	88%
08:30	(08:26)	58.8°	30.5°	61.7°	51.2°	100%
09:00	(08:56)	55.5°	36.8°	58.4°	55.0°	100%
09:30	(09:26)	51.0°	42.8°	53.9°	57.6°	100%
10:00	(09:56)	45.3°	48.4°	48.2°	59.3°	100%
10:30	(10:26)	37.7°	53.3°	40.6°	60.5°	100%
11:00	(10:56)	27.9°	57.4°	30.8°	61.2°	100%
11:30	(11:26)	15.7°	60.2°	18.6°	61.5°	100%
12:00	(11:56)	1.8°	61.3°	4.7°	61.4°	100%
12:30	(12:26)	-12.3°	60.7°	-9.4°	61.0°	100%
13:00	(12:56)	-25.0°	58.2°	-22.1°	60.2°	100%
13:30	(13:26)	-35.4°	54.5°	-32.5°	58.9°	100%
14:00	(13:56)	-43.5°	49.7°	-40.6°	57.2°	100%
14:30	(14:26)	-49.7°	44.3°	-46.8°	54.9°	100%
15:00	(14:56)	-54.4°	38.4°	-51.5°	51.8°	100%
15:30	(15:26)	-58.1°	32.1°	-55.2°	47.7°	100%
16:00	(15:56)	-60.8°	25.7°	-57.9°	42.2°	93%
16:30	(16:26)	-63.0°	19.1°	-60.1°	34.8°	74%
17:00	(16:56)	-64.6°	12.4°	-61.7°	24.9°	60%
17:30	(17:26)	-65.8°	5.6°	-62.9°	12.2°	47%

Based on the daily percentage table, the shading tool of the building works optimally 100% at 8 to 3 o'clock when the sun is rising while, at sunrise and sunset, where the sun angle is close to 360^0, the shading efficiency is reduced. Thus, the shading on the northern part of the building is efficient in covering the windows against sunlight, especially when the sun is high. Meanwhile, the north direction annual table explains that the sun is in the southern part of the building from October to February and vice versa from March to September in the South Direction.

The table below shows the annual percentages in all directions with the default model and modified percentage:

Table 3: Annual percentage of shading devices of all directions
Source: Author, 2023

Effective Shading Coefficients									
Direction	Summer			Winter			Annual		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
North (Horizontal Shades, 110cm)	0	0	100	90.1	100	36.3	55.4	58.3	79.4
South (Horizontal Shades, 110cm)	93.5	100	51.3	0	0	100	56	58.3	79.9
East (Vertical Shades, 40cm)	16.5	47.7	6.3	55.9	86	39	29.4	60.2	14.6
East Modified (Vertical Shades, 60cm depth)	29.7	49.3	21	66.7	87	42.7	39	61.2	23
West (Vertical Shades, 40 cm)	35.9	60	28	38.3	82.7	10	28.3	58.6	14.3
West Modified (Vertical Shades, 60cm with 60 degrees angle towards north)	93.9	100	76.3	54.2	78.3	5.3	76.8	91.2	39.1

The table proves that shading in the north and south directions has been optimal in covering the sun angle with an average of 90.1% in the summer north direction and 93.5% in the winter south direction. The vertical shading device covers less sun angle than the north and south directions. Furthermore, two experiments were modified with default 40 cm and 60 cm shading tools by changing the angle to 60 degrees. There was a significant change in the table numbers of the western direction shading tool, with an average annual percentage of 40 cm. The depth shading device can cover as much as 28.3%, while the shading tool with a depth of 60 cm with an inclination of 60 degrees towards the north can provide shading on an annual basis as much as 76.8%. There is a difference of 48.5%, so the building wall in the west direction can be better covered if the shading device is tilted and increased in depth.

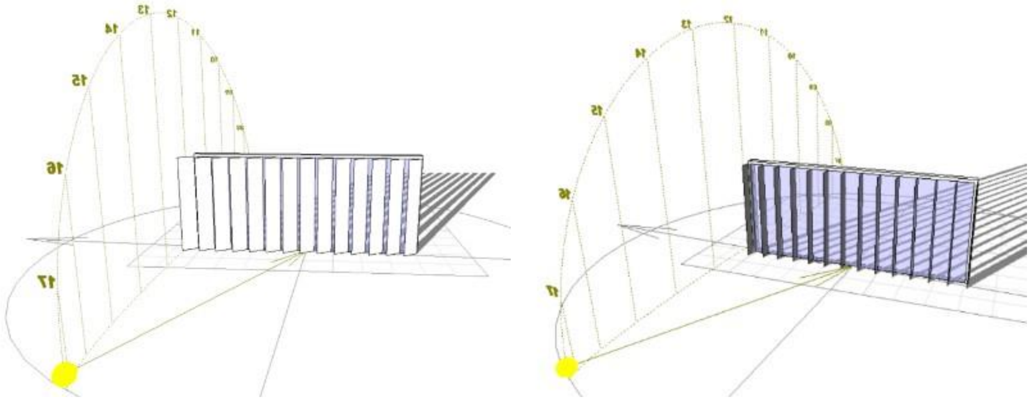


Fig. 4: Westward vertical window settings modified and unmodified
Source: Author, 2023

2) Solar Shadow Analysis on the Building Form

The tilt of the Earth's axis remains constant as the planet orbits around the sun. This tilt means that one hemisphere is tilted towards the sun at any given time, and the other is tilted away from the sun. South Sulawesi is located on the southern equator line, the sun's path shifting between the north and south throughout the year due to the southern hemisphere's winter month. On June 21, the sun is in the north and vice versa; on December 22, it is in the south, as shown on the next page.

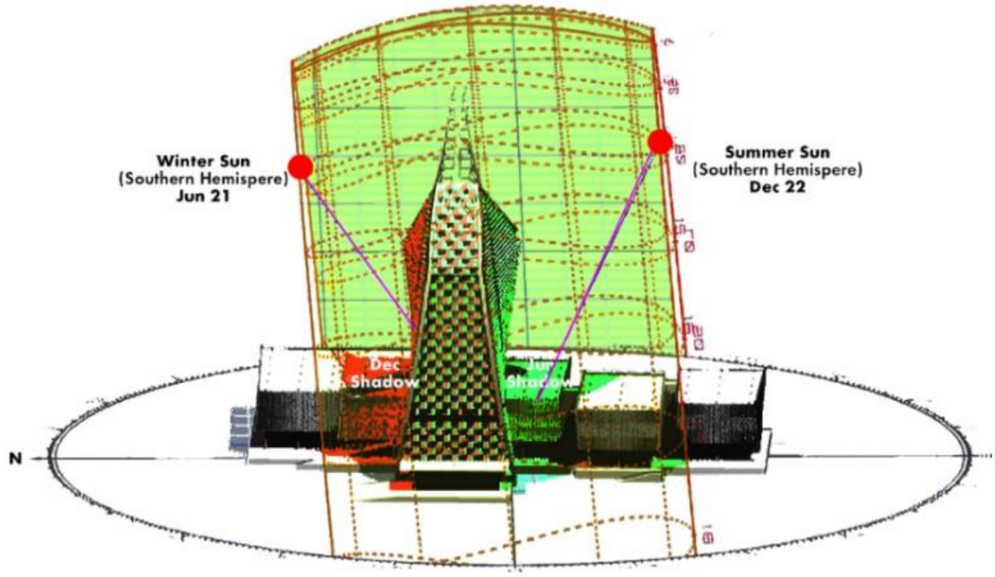


Fig. 5: Sun position on June and December
Source: Author, 2023

For this reason, the sun angle simulation is carried out in the Autodesk Forma application by looking at the shading indicator at that time.

The sun's position in June on June 22 is in the north direction, causing the southern part of the building to be covered, as in the picture above. The volume separated between buildings with proximity causes shading between buildings with each other, which can be seen from the purple indicator above. Shading tools such as trees also function to be used as natural shading.

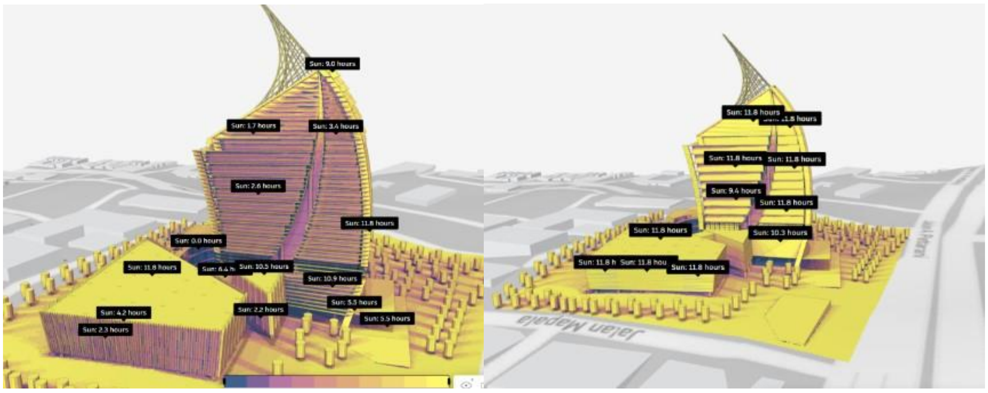


Fig. 6: Simulation on June 22 northern side of the building with and without shading
Source: Author, 2023

The comparison between the use of shading devices and those without shading is seen from the color indicator and the interval between the two. The indicator image without shading is yellow; with shading, it is a mixture of dark yellow and dark purple. The image above proves that the shading device works well when comparing time and color gradients between those two building models.

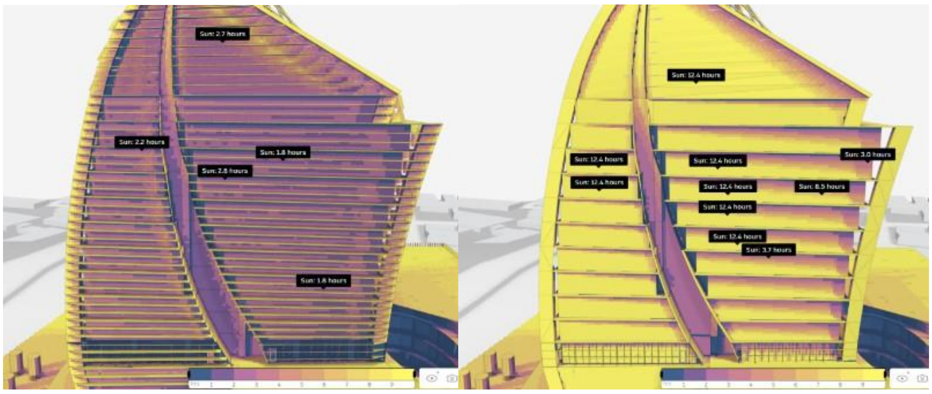
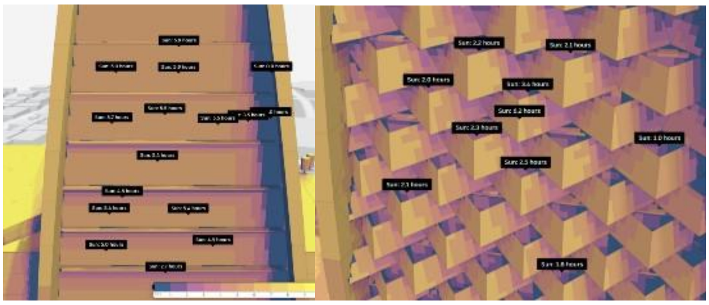


Fig. 7: Comparison on Dec 22 South facing with building shading devices and without
Source: Author, 2023

The south side of the building shows that the comparison with the use of shading devices and without shading devices can be seen from the irradiation time and color indicators. In buildings that use shading devices, the yellow indicator is only on the shading device, while the building glass is illuminated for about 1.8 to 2.6 hours when the sun is angled towards the South. Meanwhile, the building without shading devices has an overall yellow color on the surface with an irradiation time of about 8.5 to 12.4 hours on the curtain wall. Based on this figure, shading is a crucial device in the Phinisi Tower Building; without shading, the building will be easily exposed to sun exposure entering the building, which can potentially cause glare and thermal discomfort to building occupants.



(a) (b)

Fig. 8: (a) west side without second skin, (b) west side
Source: Author, 2023

The shading part of the building when the sun is almost at the same level as the building in the east of the rising sun. From the picture above, it can be concluded that the western and eastern parts of the building are covered by the sun by the building shading device in the form of a second skin. Meanwhile, the irradiation time is approximately the same, with an average of 5 hours. However, the illuminated surface is only on the surface of the second skin of the building. On the other hand, without shading devices, it gets sunlight for about 5 to 6 hours with direct sunlight exposure to the building surface.

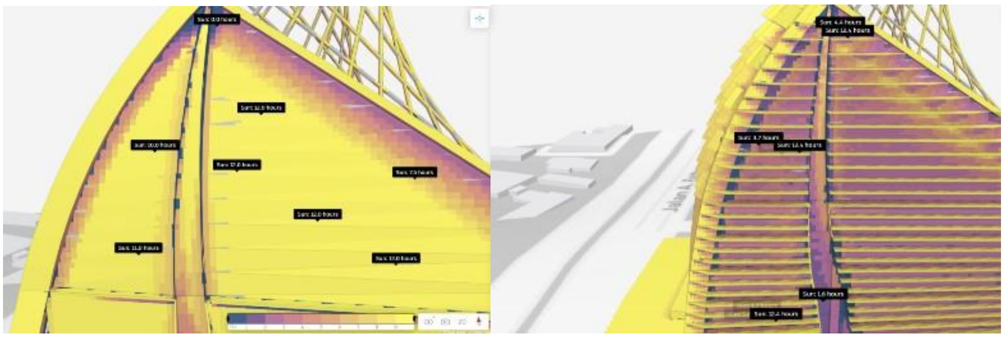


Fig. 9: Comparison on Roof Area
Source: Author, 2023

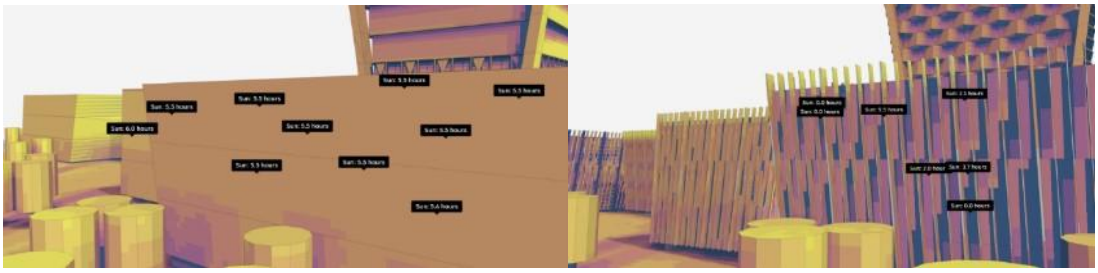


Fig. 10: Comparison on east side of the building surfaces
Source: Author, 2023

The building's top section or roof area experiences an extended sunlight exposure of about 12 hours. However, with the aid of building shading devices, this prolonged exposure primarily affects only those devices. The brise soleil shading system effectively shields the building for 0-3.7 hours, whereas the exposure lasts 5.5-6 hours without shading. Based on these simulations, brise soleil and second skin effectively act as shading mechanisms, reducing direct sunlight penetration and decreasing the time the building is exposed to sunlight.

Air Flow Analysis

The wind criteria from Windtech Consultants Planning Scheme Amendment (2017) in Melbourne C270 (2016) are as follows:

1. Sitting Comfort: a GEM wind speed of less than 3m/s for at least 80% of the time or an annual peak gust equivalent to 10 m/s.
2. Standing Comfort: The GEM wind speed is less than 4m/s for at least 80% of the time or an annual peak wind speed equivalent to 13m/s.
3. Walking Comfort: The GEM wind speed is less than 5m/s for at least 80% of the time, equivalent to an annual peak wind of 16 m/s.
4. Safety Limit: Maximum gust wind speed of 20m/s for 3 seconds with a 0.1% (annual) probability of violation from any wind direction.

Following is an analysis of the wind movement around the UNM Phinisi Tower Building.

Fig. 11: Wind movement comfort indicator around site of Phinisi building
Source: Author, 2023

Furthermore, continued by the analysis of wind movement around the site using the same application, Forma, with default settings, the wind is measured about 1.75 meters from the ground. This figure shows that the overall wind of the UNM Phinisi Tower location is in the comfort zone with a light green indicator sitting based on the comfort standard of wind speed being less than 3-10m/s maximum and a dark green indicator indicates standing from 4-13m/s maximum.

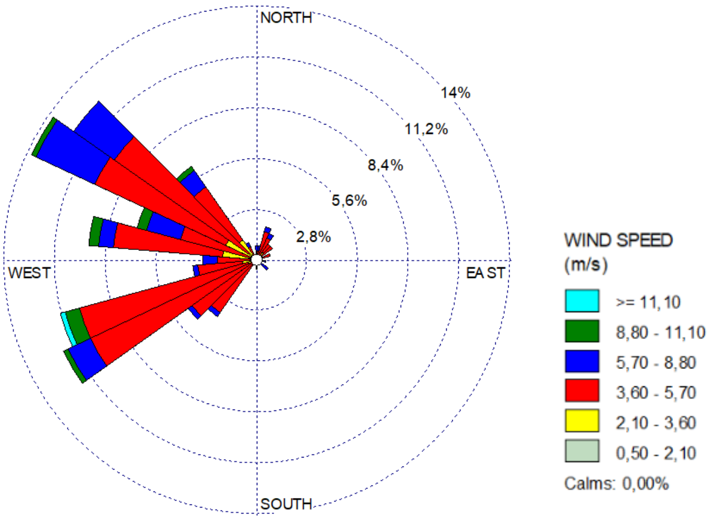


Fig. 12: BMKG Wind Direction and Speed Data Throughout 2022
Source: BMKG, 2022

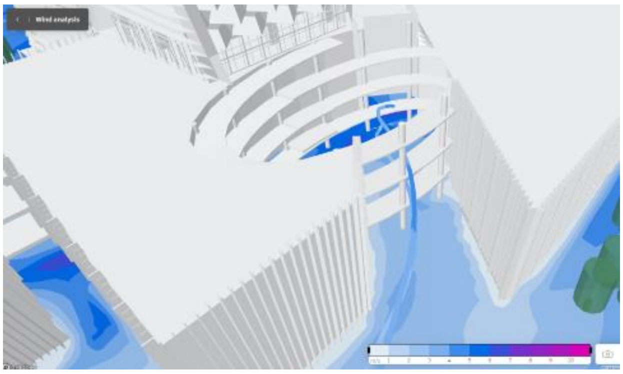


Fig. 13: Wind Movement from the Southeastern at Courtyard
Source: Author, 2023

The open and elevated form of the Phinisi UNM building on the ground floor causes easy access to wind throughout the building. The building can drain passive natural energy by utilizing the wind potential at the location where the building stands. The shape of the building can affect the flow of wind around and inside it. Aerodynamic design can encourage the wind to flow smoothly around the structure, thus increasing its cooling potential.

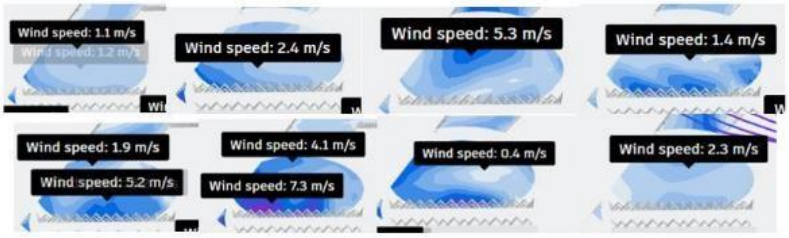
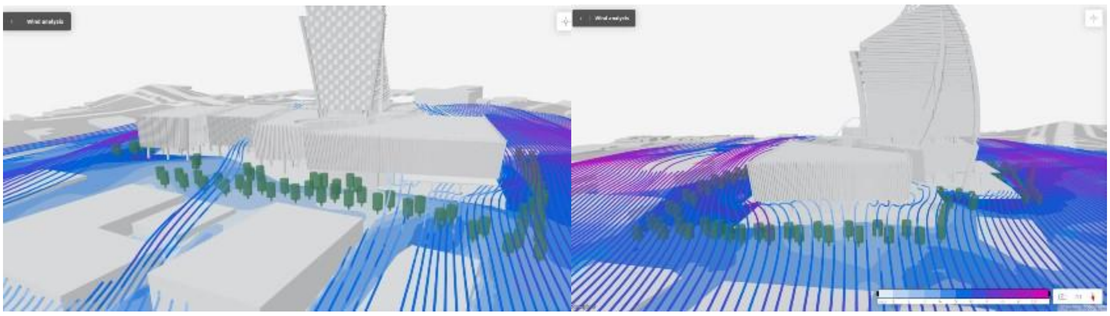


Fig. 14: Wind Movement from all directions of the Courtyard
Source: Author, 2023

The building layout is divided into four open sections interconnected to promote effective cross-ventilation using wind. Wind catchers and a central chimney are in the courtyard or pond section. Wind catchers or smokestacks are integrated into the building structure. The openings on opposite sides of the building encourage airflow from one side to the other. The courtyard area experiences peak wind speeds of up to 7.3 m/s from the Southeastern direction.



(a) (b)

Fig. 15: (a): Wind Movement from the East of the Building, (b): Wind Movement from the North of the Building
Source: Author, 2023

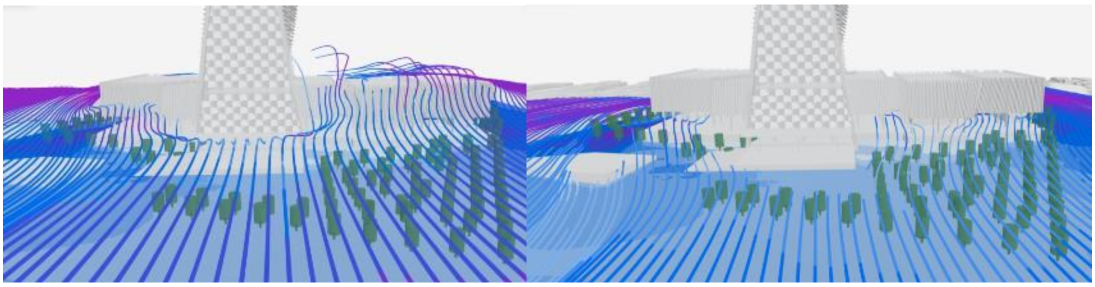


Fig. 16: Comparison wind moves westward by directing it towards the walls of the building
Source: Author, 2023

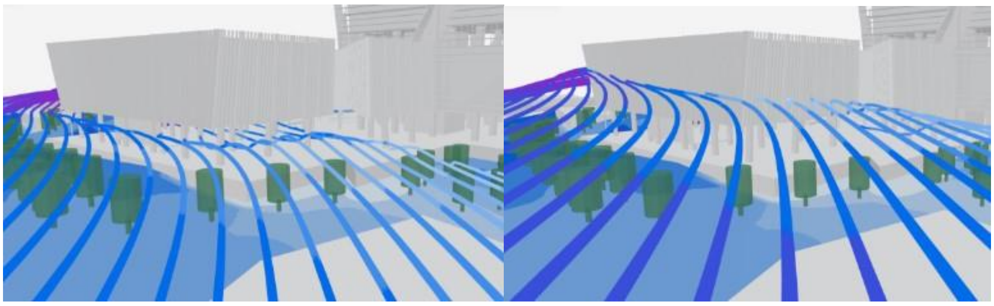


Fig. 17: Comparison Southwest wind movement towards walls and building voids
Source: Author, 2023

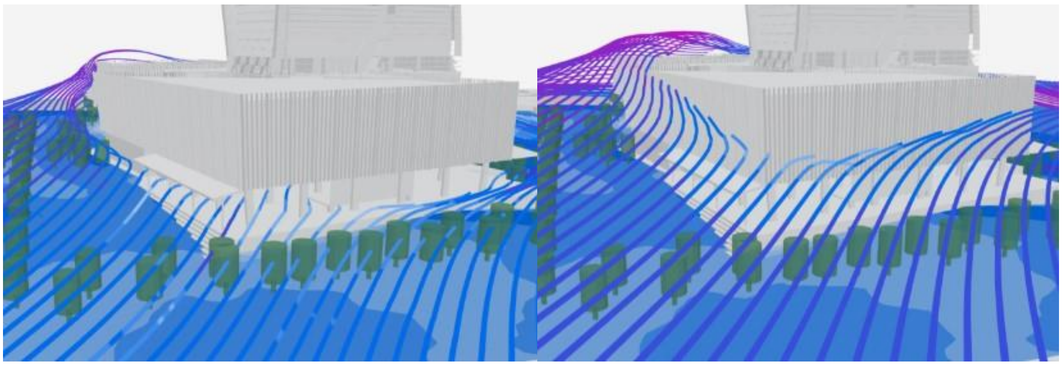


Fig. 18: Comparison of Wind movement in the northeast direction towards the walls and the building voids
Source: Author, 2023

From the illustration provided, it is evident that the UNM Phinisi Tower Building design allows for unobstructed airflow within its premises. No significant barriers, like walls, hinder the wind's natural course. The absence of partitions in the model ensures that the ground floor is continuously bathed in refreshing breezes. Moreover, the semi-outdoor design concept of the Phinisi building, combined with its elevated structure, ensures adaptability to shifting wind patterns, accommodating breezes from any direction. This strategic architectural decision ensures thermal comfort and contributes to a sustainable and energy-efficient environment within the tower.

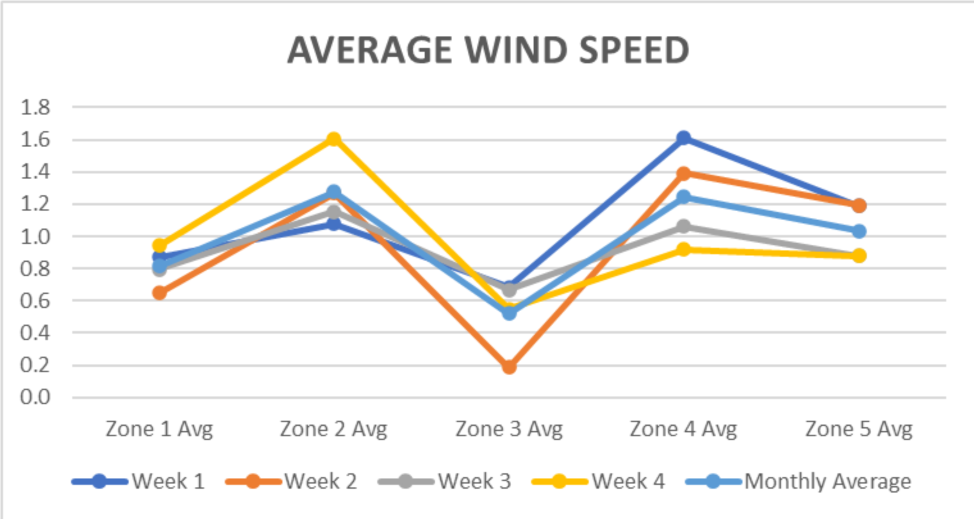


Fig. 19: Comparison of average wind speed between 5 Measurement Points
Source: Author, 2023

Table 4: The Effect of Wind Speed
Source: Frick, 1998

Wind Speed (m/s)	Refreshment Effect	Indicator
<0.25	^{0}C	Not perceivable
0.25 - 0.5	0.5 - 7 ^{0}C	Most Comfortable
0.5 - 1	1.0 – 1.2 ^{0}C	Still Comfortable
1 - 1.5	1.7 - 2.2 ^{0}C	Maximum
1.5 - 2	2.0 – 3.3 ^{0}C	Less comfortable, windy
>2	2.3 – 4.2 ^{0}C	Occupant health is affected by wind.

Wind calculations were carried out for one month, from mid-July to mid-August. The lowest wind speed zone is in zone 3, in the cafeteria section. This section is very close to the density of trees west of the building and almost at the same level as the building. Meanwhile, other zones where the trees are further away with a lower elevation than the building have higher indicators. Based on the shielding effect, according to Frick, the wind speed is between the maximum and still comfortable, within the range of 0.5-1.3m/s.

Temperature Balance Analysis

1) Annual Sunlight Exposure Analysis

Furthermore, calculations were carried out by testing with two models of the UNM Phinisi Tower. The first model is without a shading device, and the second is with a building shading device.

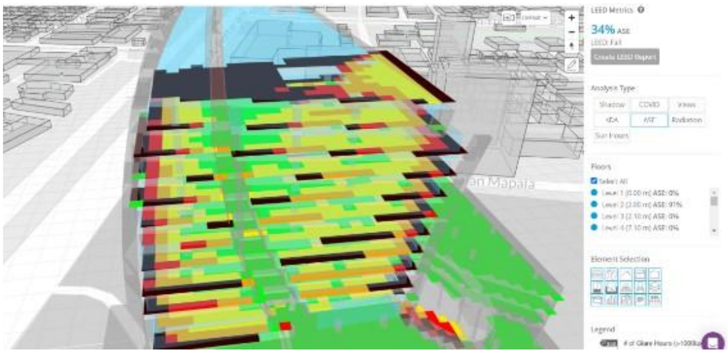


Fig. 20: ASE value and indicator without shading device
Source: Author, 2023

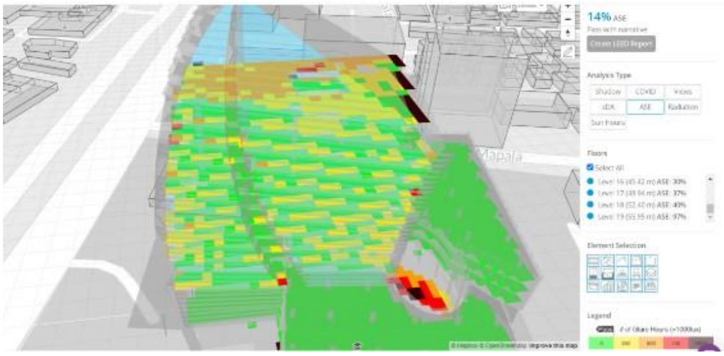


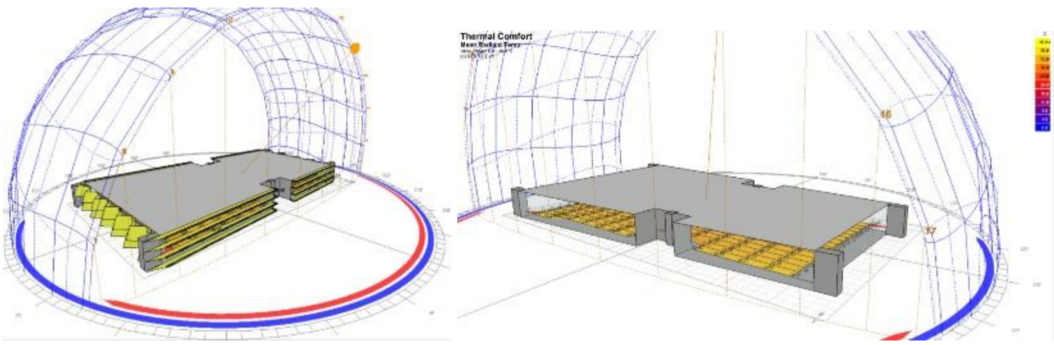
Fig. 21: ASE value and indicator with shading device
Source: Author, 2023

Excessive sunlight exposure can result in discomfort due to extreme heat or glare. By optimizing building design based on ASE (Annual Sunlight Exposure), both thermal and visual comfort within the interior spaces can be enhanced. ASE value quantifies the degree of overexposure to sunlight. This information aids in the sizing and placing of windows and other openings to maximize natural light while minimizing glare and excessive sun exposure. ASE calculations are derived from "LEED v4.0 - IEQ c7 Daylight, Simulation: Spatial Daylight Autonomy" and "IES LM-83 (Covetool, 2023)."

Based on the ASE values on both models, the first model with shading devices resulted in 14% and passed the test, while the second model's ASE simulation failed to meet the LEED standard with a percentage of 34%, showing a 20% difference. Dark ASE indicator colors in the simulation results signify that the excessive heat in those dark-colored indicators needs to be addressed, possibly by adding building shading devices, geometry changes, or reducing the window size on that side. These ASE values serve as benchmarks for the level of solar radiation that may cause discomfort, aiming to improve sustainability, energy efficiency, and the overall performance of the building. Yearly sun exposure on the building's exterior surfaces can lead to high cooling loads, elevated temperatures, and increased energy consumption. Utilizing the current second design model with shading devices is a strategy to reduce energy consumption and operational costs.

2) Mean Radiant Temperature

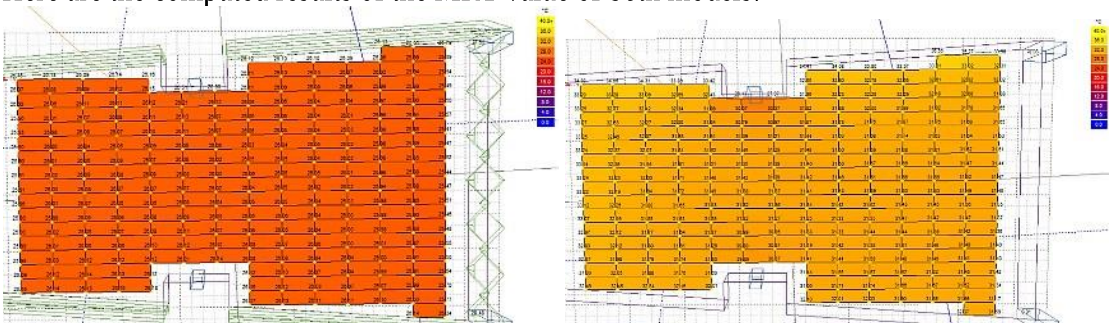
A simulation was conducted on the 5th floor using Ecotect software to understand the average temperature within the building. According to Jamala (2015), floors 5 to 17 have a typical layout. Two models were created for the simulation, both using the same materials. However, one model incorporated shading devices similar to those in the Menara Phinisi building, while the other did not include any shading features. Both simulations were run for June 21, corresponding to the Southern Hemisphere's winter season. The average temperature was assessed using the Ecotect application's Mean Radiant Temperature (MRT) value. Both design models appear transparent in the images, made from glass.



(a) (b)

Fig. 22: 3D Modelling Comparison (a) with shading Devices (b) without shading devices
Source: Author, 2023

Here are the computed results of the MRT value of both models:



(a) (b)

Fig. 23: Comparison Mean Radiant Temperature between (a) with shading Devices (b) without shading devices
Source: Author, 2023

Based on the color indicator, the figure above illustrates a lighter indicator towards yellow hue, illustrating that the hotter the room's temperature will be, the lower the temperature, the darker the color will tend to be or become more blueish. In models that do not use shading tools, the indicator is dark yellow, while in those using shading tools, the indicator is dark orange. This means that the lowest temperature occurs in buildings equipped with shading devices. The two models have a temperature difference, with a range of 6 to 8 degrees Celsius difference. The temperature differences illustrate that shading devices such as brise soleil and second skin on the building have reduced heat or temperature in the room at the UNM Phinisi Tower.

3) Solar Access Analysis

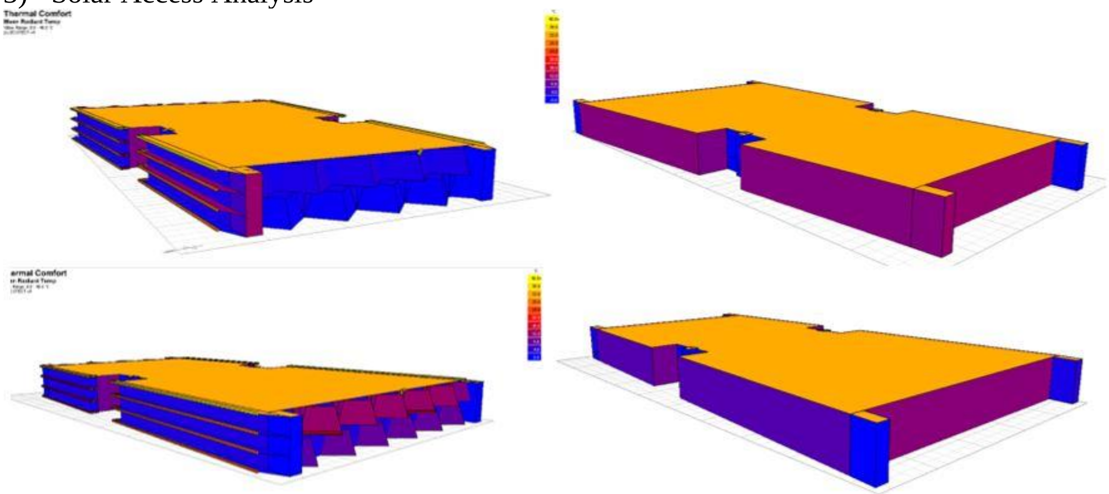


Fig. 24: Comparison of solar access between 4 sides of the building
Source: Author, 2023

Solar Access Analysis with the setting for a year from January 1 to December 31 with a time range of 08:00 to 17:00. From the figure above, it can be seen that the building surface appears blue overall in the analysis with the shading tool. The more the blue color the indicator identifies, the lower the surface temperature on the building volume. There is also a light and dark purple hue on the eastern part of the building in the first model building with the shading tool. The building shading device appears orange and red, and the difference in the indicators of the two models, one of which appears blue, indicates that the building shading is functioning optimally to shield the building from the sun's heat.

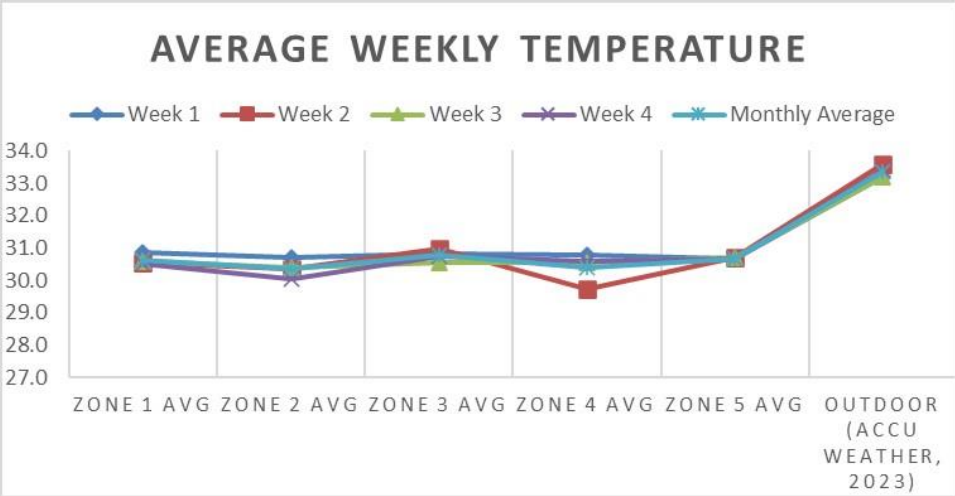


Fig. 25: Comparison of average weekly and monthly temperature between 5 Measurement Points + Outdoor
Source: Author, 2023

Table 5: Indicators of thermal comfort
Source: SNI 03- 6572-2001

Temperature (^{0}C)	Indicator
20.5 – 22.8 -24	Upper Comfortable Cool
20.8 – 25.8 - 28	Upper Optional Comfort
20.8 – 25.8 - 31	Upper Comfortable Warm.

Measurements were taken at five different points on the building's ground level, a semi-outdoor design. According to the comfort indicators specified by SNI 03-6572-2001, the temperature range at these five measurement points fell within the upper warm zone, ranging from 30-31 degrees Celsius. No significant differences in temperature were observed across these five points. The lowest average temperature was 29.7 degrees Celsius, and the highest was 31.00 degrees Celsius. The warmest zones were located in the northern part and near the cafeteria among the five measurement points. A temperature difference of about 3 degrees Celsius was noted between the semi-outdoor and outdoor areas of the building.

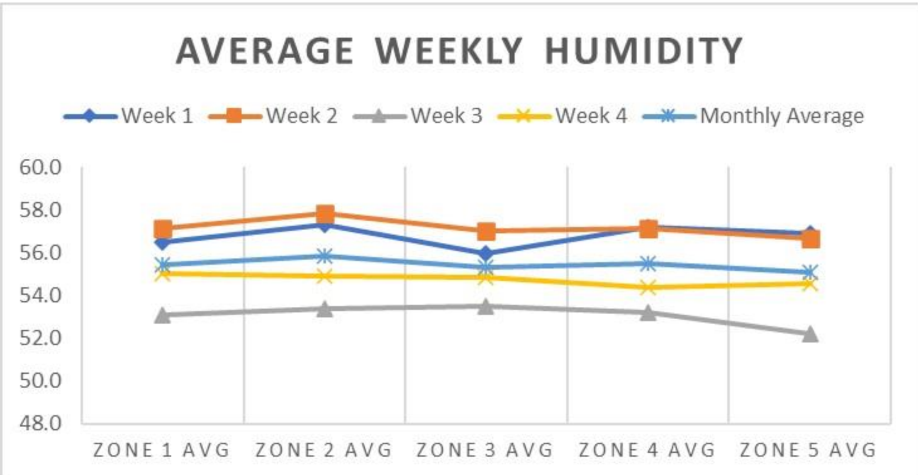


Fig. 26: Comparison of average weekly humidity between 5 Measurement Points
Source: Author, 2023

Table 6: Indicator of Moisture comfort
Source: Bauer et al., 2010

Humidity Level (RH)	Indicator
Below 30%	Respiratory Disturbances
Recommended 30-60%	Relative Humidity
Above 70%	Condensation, Mold Growth

The humidity measurement results show that the average relative humidity falls below 60%. The monthly averages across the five measurement points range from 55.1% to 55.9%. According to the comfort mentioned before indicators for humidity, these levels are within the recommended range for relative humidity.

Table 7: Analysis and review based on several simulation software
Source: Author, 2023

Software	Analysis
Building Shadow Analysis Using Ecotect Solar Tool	Based on the analysis, there is a variation in the average coefficient of vertical shading devices when modified by tilting them at a 60-degree angle and increasing the depth of the shadow from the actual 40 cm to 60 cm. Specifically, the shading coefficient changes from 28.3 for the standard configuration to 76.8 with the modifications. This suggests that alterations to the vertical shading apparatus are needed to reduce the sunlight penetration intervals. For the horizontal devices, when measuring the yearly percentages for both summer and winter, the average shading efficiency was 93.5% for devices facing south and 90.1% for those oriented in the southern direction. Consequently, horizontal shading devices are effective in blocking sunlight.
Building Shadow Analysis Using Autodesk Forma	The effectiveness of shading devices compared to structures without them is apparent from the color indicators and the intervals between the two scenarios. In the absence of shading devices, the indicator image is yellow, while with shading, the print displays a combination of dark yellow and dark purple. The sun exposure interval for surfaces without vertical shading devices ranges from 6 to 5 hours, whereas models with shading devices experience exposure ranging from 0 to 3.7 hours, mainly on taller building surfaces. For horizontal shading, the sun exposure interval without any shading device ranges from 3 to 12.4 hours, contrasting with an interval of 1.8 to 2.7 hours when shading devices are employed. Regarding second-skin shading devices, the shadow duration without any shading ranges from 2.3 to 5.9 hours. In contrast, with the shading device, a yellow appearance is visible on the surface of the shading device, and the interval narrows to 0 to 2.5 hours. The evidence confirms that the shading devices are adequate, as evidenced by the differences in color gradients and exposure durations between the two building models.
Airflow Analysis Using Autodesk Forma	The open design of the ground floor in Phinisi-style buildings allows for unobstructed air movement through the lower levels of the structure. This architectural feature facilitates natural ventilation, making it easier for occupants to experience improved air circulation within the building.
Temperature Balance Analysis Using Covetool	Based on the ASE (Annual Sunlight Exposure) values, the image on the top without shading devices shows 34%, while the image at the bottom with shading devices indicates 14%. These results confirm the effectiveness of the shading devices in the ASE test. ASE values act as metrics for the extent of solar radiation that might lead to discomfort. The aim is to enhance sustainability, energy efficiency, and overall building performance. Adopting the second design model equipped with shading devices serves as a strategy for reducing energy consumption and operational expenses.
Temperature Balance Analysis Using Ecotect	The MRT and solar access analysis indicate that the shading devices effectively lower the building's surface temperature, as evidenced by the indicators. The two models have a temperature discrepancy, showing a difference of 6 to 8 degrees Celsius.

Conclusions

Based on analyses conducted with Ecotect and Autodesk Forma software, the shading mechanisms—namely brise soleil and second skin—effectively mitigate solar exposure on various parts of the Phinisi building, especially at diverse sun angles. For example, the second skin becomes crucial in shielding the building from direct sunlight during sunrise and sunset when the sun's angle is between 270° and 360°. Additionally, the horizontal brise soleil features on the main Phinisi UNM Makassar building work remarkably well. In simulations using Ecotect's solar tool, these shading systems effectively block an average of 90% of solar exposure from northern and southern directions. Conversely, vertical shading elements only offer an average coverage between 14% and 60%. Assessments made through the Forma software, which considers both the duration and intensity of sunlight, confirm the optimal performance of the shading devices on UNM Makassar's Phinisi Tower.

The airflow analysis of the Phinisi Tower using the Forma application indicates that the elevated design of the tower promotes wind flow at the building's base. The airflow within the Phinisi Tower remains comfortable, as indicated by the "sitting and standing" benchmarks. This indicator indicates that the average wind speed is less than 3-4m/s for at least 80% of the time, consistent with the annual peak wind speed of 10-13m/s, as evident from the BMKG 2022 annual wind speed graph. Based on Frick's shielding effect, the wind speed falls comfortably between the 0.5-1.3m/s range.

In analyzing the temperature balance within the Phinisi Tower, two models were compared: one with shading devices and one not using them. The ASE simulations in the Covetool application show that the ASE values passed the ASE test. This ASE simulation suggests that the model without shading devices requires more cooling energy or needs model modifications to reduce cooling loads. From the solar access analysis using the Ecotect software, the shaded model displays lower temperature indicators. The MRT (Mean Radiant Temperature) simulations for both models show a temperature difference of 5-8 degrees, with the shaded model having a lower temperature indicator. Based on the SNI 03-6572-2001 comfort indicator measurements, the temperatures range between 30-31 degrees, and humidity levels of 55.1-55.9 are at the relative humidity.

Given the above three variables, the Phinisi UNM building exemplifies an ecologically sustainable high-rise structure, especially regarding its effective shading devices. Observations from the Phinisi UNM building allow us to understand the responsiveness of shading devices at specific sun angles. The elevated or stilted design of the Phinisi Tower could inspire the planning of other multi-story buildings in tropical climates.

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