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Experimental Study on Design of External Shading Devices in Dental Unit Room

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Abstract. Experimental study using software simulation is frequently employed as a tool to minimize errors in design and predict design decisions. In addition to considering the functions of the building and other requirements, architects are required to understand the context and possess the ability to optimize the climatic potential of the construction site. Solar gain is a crucial factor, as insufficient sunlight entering a space can result in inadequate illumination, while excessive sunlight can increase the building's heat gain. Therefore, the key to success in design lies in optimizing lighting and heat gain proportionally to address these challenges. This research utilizes an experimental method by identifying the location, orientation, material, and function of the space. The objective of this study is to find an optimal external shading device for shading the Dental Unit area in the Central Laboratory building at the Diponegoro University. The results of the research indicate that the use of 3 types shading devices can reduce the average sunlight gain by 10-15%, offering significant potential for lowering energy consumption in the Central Laboratory building of the Faculty of Medicine at Diponegoro University in Semarang, Indonesia.

Keywords: experimental, shading device, temperature, daylight analysis, dental unit

1. Introduction

The exploration of external shading devices has captivated the attention of professionals in the realm of architecture and building design. The fundamental aspect of various fields lies in the use of experimental research designs (Turner, 2020). Health buildings such as central laboratories have many facilities in there including several functions such as The Dental and Oral Hospital also a classroom for students. The building sector presents challenges and opportunities towards decarbonization, and there is a critical need to address energy and environmental realities in this sector (Santamouris & Vasilakopoulou, 2021). In addition, the potential for energy savings in commercial buildings, including laboratories, can reach 10-30% of their energy consumption (Kartika, 2018).

Figure 1. 1. Central Laboratory Building (2023)

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The previous selection being a sample of measurement is a Dental unit room on 5th floor. There are 9 rooms of Dental Unit Rooms which the research chooses one of them based on Orientation of the building and the type of walls is dominant of glass (figure 1.2).

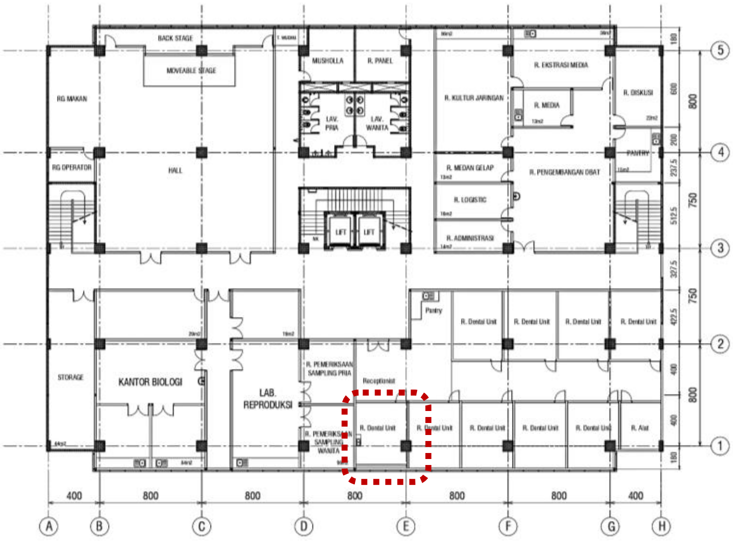


Figure 1. 2. 5th Floor of Central Laboratory (2023)

According to Minister of Health Regulation no. 40 of 2022 concerning Technical Requirements for Hospital Buildings, Infrastructure and Health Equipment states that the Dental Unit or Dental Examination and Consultation Room must have a room temperature of 24°±2°C. In research conducted by Al-Tamimia & Fadzila (2011) on high-rise residential buildings in hot-humid climates, horizontal shading devices were found to reduce indoor temperatures by 0.61-0.88°C. Furthermore, Ramawangsa (2015) found a kinetic sun shading design with a rectangular geometric sun shading model that was able to approach visual comfort standards with an opening of 55%, a shadow percentage value of 67%, 33% light in September. Also, by Jelani, et al (2019) through experimental methods, effective vertical sun shading with a grid design can reduce temperature by 2℃-8℃ and reduce humidity by 2%-6%. Analysis of facade modelling using horizontal sun shading found the maximum glare index at 6.34 at 06.00-11.00 a.m., this figure is in the unnoticeable category in the Szokolay glare index with a glare index value of 0-10 (Ramadona, 2017). Types of sun shading that can reduce heat include horizontal louver overhangs, vertical fins and egg crates (Nabela & Putranto, 2019). Studies also state that the thermal performance of building solar shading devices is capable of achieving a 38.7% reduction in incoming heat energy during the summer (Evangelisti, et al, 2020).

Through simulation research, it has been discovered that devices like louvers, blinds, and shades play a crucial role in managing the sunlight entering a structure, thereby regulating its internal temperature. This study aims to assess the efficiency of various external shading devices in mitigating solar heat gain. Utilizing Autodesk Ecotect software analysis, the investigation delves into the primary factors influencing the performance of external shading devices. The outcomes of this analysis offer valuable insights for designers and engineers, aiding in the selection of appropriate materials and the determination of installation methods for external shading systems.

2. Research Methods

This study proposes study is to find an optimal external shading under a simulation software using Autodesk Ecotect within a real time that involves identifying the location, orientation, sun direction, measuring room area, ceiling height, and window size.

The simulation can run to obtain an optimal recommendation for the Dental Unit space in the Central Laboratory building at Diponegoro University. The procedural steps in the simulation conducted by the researcher are as follows:

a. Redrawing the existing layout using Autodesk AutoCAD software
b. Redrawing the 3D model using SketchUp software
c. Importing the file into Autodesk Ecotect software in .3Ds format
d. Adjusting the climate data for Semarang city to default settings to obtain the most accurate simulation
e. Subsequently, selecting the time, date, and sky conditions, with a preference for a representative date aligned with the field data collection date, which is September 24th 2023.

3. Results and Discussion

3.1 General Specification

To conduct this experiment, a sample building was selected and fitted with various shading devices on its windows. The amount of solar radiation entering the building was measured using Data Logger placed at Dental Unit Room inside. The data collected over a period of time allowed for an analysis of the performance and efficiency of each shading device. The Dental Unit is one of the room parts by Dental and Oral Hospital.

Figure 3.1. The Dental Unit Room (2023)

As for the physical data of the Central Laboratory Building managed to collect was orientation building (table 3.1.1), research area specifications (table 3.1.2), windows specification (3.1.3), and glass selection (table 3.1.4).

Table 3.1.1 The Building Orientation

General Data	
Function	Central Laboratory
Number of Floors	5
Area	7440 m^2
Specific Data	
Research Area	Dental Unit Room
Area	21.58 m^2
Main Orientation	Northeast
Latitude	-7.047
Longitude	110.443

The main focus of this research on this building on the Dental Unit Room located on the 5th floor with existing room specifications data (Table 3.2).

Table 3.1.2 The Dental Unit Room Specification

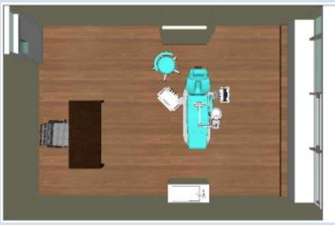
Visualization	Description	
	Length	4.15 m
	Width	5.20 m
	Area	21.58m²
	Plafond Height	2.85 m
	Colour of Walls	Cream
	Colour of Plafond	White

Table 3.1.3 Window Specification

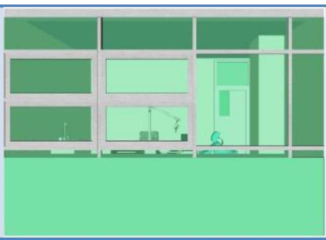
Visualization	Description	
	Length	1.15 m
	Width	0.95 m
	Glass Materials	Panasap Green 6mm
	Frame Materials	Alumunium Grey

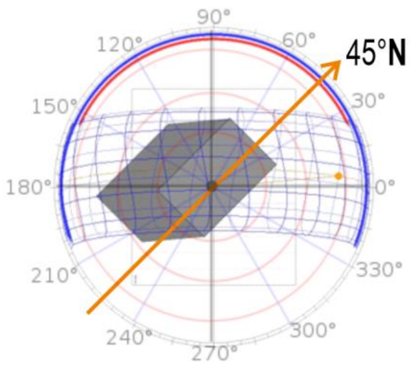
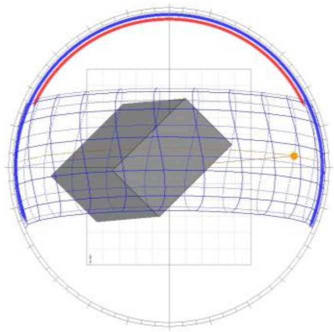
Table 3.1.4 Glass Spesification

No.	Data	Solar Factor (%)	Shading Coeficient	U Value (W/m^{2}K)
1.	Panasap Green 6 mm	55	0,63	5,7

Source: (amfg.co.id, 2024)

The subsequent simulation process should align with the current conditions by first confirming the dean's actual orientation through validation (Table 3.1.5)

Table 3.1.5 Orientation of The Building

Existing Orientation	Simulation Orientation
Real 45°N	Simulation 45°N
	

3.2 Field Observation Data of Air Temperature and Relative Humidity

This data was taken on 24th September 2023 using Data Logger from 08.00 a.m. until 04.00 p.m. The air temperature of Dental Unit Room shows up to 33.47°C with a minimum of 31.9°C at 04.00 p.m. and a maximum of 34.2°C at 10.30 a.m. accompanied by an average air humidity of 41.69% with a minimum humidity was 33.8% at 11.00 a.m. and a maximum of 56.4% at 08.00 a.m. **(figure 3.2).** According to guidelines from the Occupational Safety and Health Administration (OSHA) (DANB, 2023), the temperature within a dental office should ideally range between 68-76°F (20-24°C), while maintaining a relative humidity of 20-60%. It's crucial to regulate the temperature in dental surgery suites to ensure consistency and appropriateness throughout (energy5.com, 2024). Additionally, utility rooms within dental offices must maintain cleanliness and controlled temperatures for optimal equipment performance (dentalez, 2023). Moreover, the heat produced during dental procedures can impact intrapulpal temperature (Lau, et al., 2023). Therefore, climate change and extreme weather events can impact air temperature levels, posing additional challenges in maintaining a comfortable environment in dental units (Hackley, 2021).

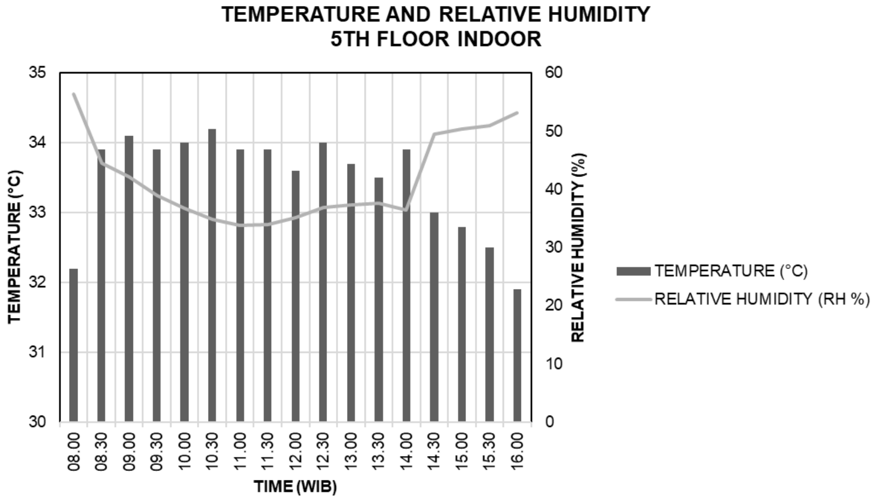


Figure 3.2. The Data of Air Temperature and Relative Humidity (2023)

3.3 Simulation

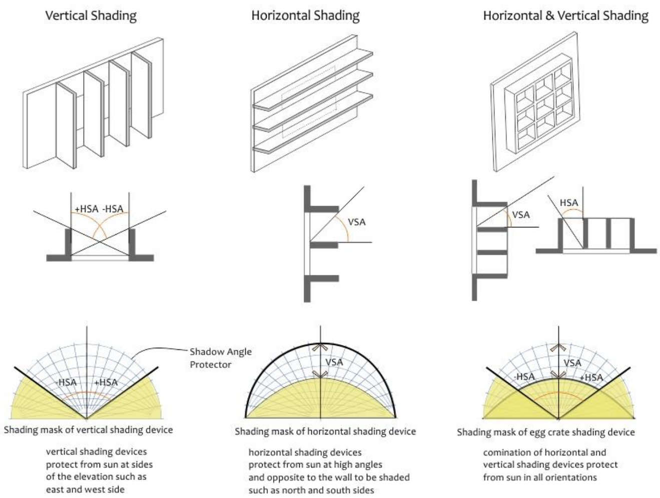


Figure 3.3. The Common Types of Shading Device (Lechner, 2001)

The common types of external shading devices, such as shutters, awnings, canopies, blinds, and protruding horizontal and vertical fins, play a crucial role in minimizing solar radiation. When appropriately planned, these sun controls prove to be highly efficient in reducing absorbed heat by dispersing it externally. Whether fixed, adjustable, or retractable, these devices need careful design to ensure that direct radiation does not impact the window during specific times of the day and throughout the year (Legg, 2017).

The existing daylighting Dental Unit Room in Central Laboratory measured at 5th floor 2 **(figure 3.4)** shows the daylight factors is up to 68%.

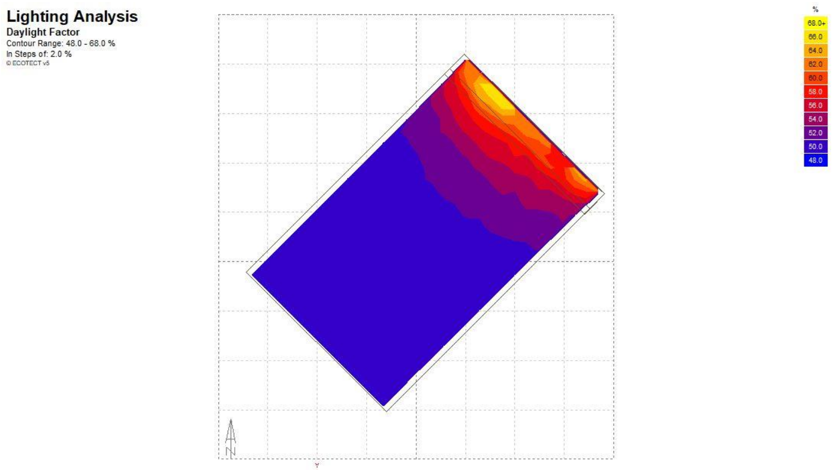
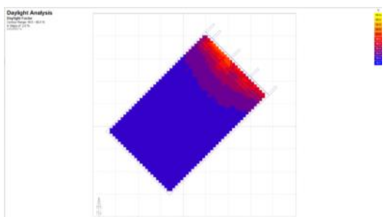
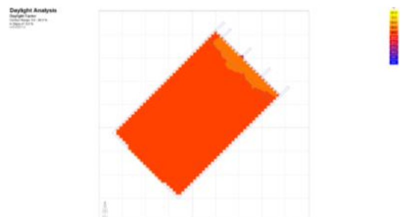
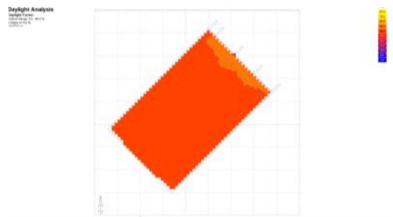
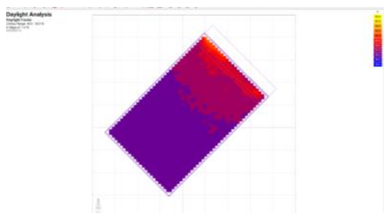
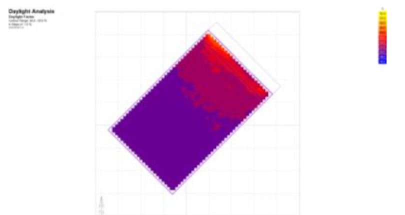
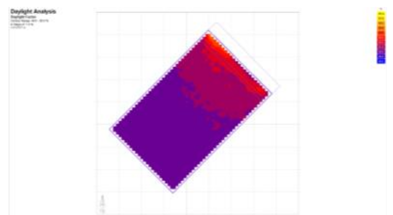
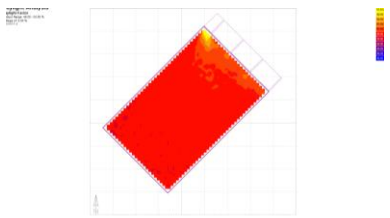
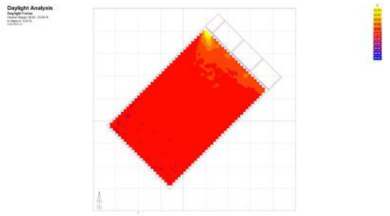
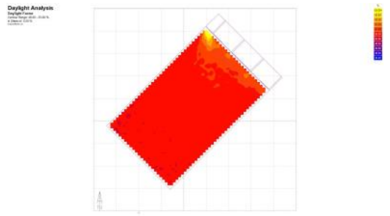


Figure 3.4. The Existing Daylight Analysis (2023)

The simulation with difference 3 times at 08.00 a.m., 12.00 a.m., and 04.00 p.m. applying the same date with field observation. Additional with shading devices can reduce to optimum daylight in the room (Table 3.3).

Table 3.3 Simulation

08.00 a.m.	12.00 a.m.	04.00 p.m.
Vertical Shading Devices		
 Daylight factors reach up to 48-68%	 Daylight factors reach up to **80%**	 Daylight factors reach up to **80%**
Horizontal Shading Devices		
 Daylight factors reach up to 48-58%	 Daylight factors reach up to 48-58%	 Daylight factors reach up to 48-58%

Eggcrate Shading Devices		
 Daylight factors reach up to 48-**53%**	 Daylight factors reach up to 48-**53%**	 Daylight factors reach up to 48-**53%**

3.4 Results

The outcomes of the Ecotect software simulation are compiled and presented in a table for convenient reference and comparison. However, it's important to note that the daylight simulation doesn't incorporate air temperature and relative humidity data obtained from field measurements. The results encompass all simulations involving various types of shading devices implemented on wall facades (Table 3.3). Vertical shading devices can't reduce significantly which is at 12.00 a.m. and 04.00 p.m. the contour range value of daylight factor increase until **80%**. Horizontal shading devices is capable to reduce until **10%** from the existing based on one day simulation. The third of shading device type is Eggcrate (combination) can reduce until **15%** of daylight factor on three times simulation which is the best type of shading devices.

The external shading devices results revealed significantly reduced solar heat gain in all cases. Louvers were found to be particularly effective in blocking direct sunlight while still allowing natural light to enter the building and also can reduce the air temperature according to standards. Blinds and shades also provided substantial reduction in solar radiation but had a slightly lower efficiency compared to louvers (Shahdan, Ahmad, & Hussin, 2018).

4. Conclusion

In summary, this paper has successfully achieved its objective of investigating how various configurations of external shading devices impact daylight analysis through computer simulations. The results from Autodesk Ecotect simulations unequivocally indicate that the egg-crate shading device emerges as the most effective solution for tropical-humid climates, utilizing a blend of both horizontal and vertical shading elements. These external shading devices have the potential to mitigate heat gain, thereby lowering air temperatures and enhancing air conditioning performance. By integrating external shading devices into architectural designs, not only can energy consumption be reduced, but also the overall comfort and well-being of occupants can be enhanced. Additionally, future research could explore the long-term performance and durability of various shading devices in real-world applications, further refining their effectiveness in optimizing indoor environmental quality. Ultimately, this study contributes valuable insights to the field of sustainable architecture, emphasizing the crucial role of passive design strategies in creating healthier and more energy-efficient built environments.

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