Study on the Application of ETFE Material on Building Envelopes in Relation to Indoor Thermal and Visual Comfort Case Study: South Quarter Dome Building, Jakarta

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ABSTRACT

For the past two decades, energy issues have been in the spotlight in building construction and design. Environmental damage such as global warming, climate change and energy crisis are challenges that need to be considered by the entire community. These problems greatly affect our lives in the future, air pollution, increasing city temperatures (urban heat island), and declining environmental quality affect human comfort and health. This study discusses the effectiveness of ETFE (Ethylene Tetrafluoroethylene) material on the South Quarter Dome building, South Jakarta, in improving thermal and visual comfort through temperature insulation and light transmission. This study aims to determine the performance or effectiveness of using ETFE material on building facades to improve the comfort of indoor spaces. The method used is mixed methods, which combines two research techniques with research variables, namely air temperature (°C) on thermal comfort and lighting intensity (lux) on visual comfort. The results of this study indicate that the magnitude of the light transmission measurement value on the visual comfort of the South Quarter Dome is 1-95% and the magnitude of the decrease in outside to inside temperature is 0.2-1.3 °C. This shows that ETFE material is able to control natural lighting well, which can minimize the use of electricity for artificial lighting and has good ability to regulate temperature, so it can create thermal comfort for its occupants.

Keywords: Environmental damage, Material, ETFE, Lighting Intensity, Air Temperature.

1. Introduction

Over the past two decades, energy issues have become a focal point in building construction and design. Environmental damage such as global warming, climate change, and the energy crisis presents challenges that need to be addressed by society as a whole [1]. Energy security, a multifaceted concept that impacts the economy, environment, and technology, has evolved into an interdisciplinary field due to climate change and the uncertainties surrounding fossil fuel availability [2]. Researchers attempt to address environmental conditions affecting variables such as reflection, spectral response, irradiation, temperature, and nominal output power, which influence the efficiency of solar cell modules throughout the day and year, by using nanophase materials and phase-change materials to reduce the temperature of photovoltaic panels. [2]. The implementation of green buildings in Indonesia contributes to the global commitment of the Government of the Republic of Indonesia regarding global warming by reducing carbon emissions by 26% by the year 2020, as buildings have been responsible for producing 30% of the world's carbon dioxide emissions. [3]. This condition has led to the need for the use of materials in building construction as one of the solutions to reduce environmental degradation.

The application of materials in buildings should be able to minimize artificial energy use with the aim of maximizing natural lighting and ventilation experienced by the occupants. Materials such as low-emissivity (low-e) glass, photovoltaic panels, and Ethylene Tetrafluoroethylene (ETFE) make a positive contribution in a more efficient way, from utilizing natural lighting and air circulation to providing protection against weather changes.

Materials in the context of building design are closely related to efforts in creating several important aspects, such as thermal comfort. The right selection of materials, combined with a thoughtful design concept, will result in a healthy building for its occupants, while also supporting sustainability and preserving environmental quality. The building envelope (façade), which serves as the primary barrier between the interior and exterior of the building, plays a crucial role in supporting this sustainability. Therefore, using façade materials that are responsive to environmental conditions is essential.

The building envelope can maximize the entry of natural light while controlling the amount of heat entering the interior, thereby allowing the design and material selection of the envelope to indirectly reduce the need for artificial lighting and cooling. Several strategies can be implemented, such as selecting low-emissivity glass or ETFE membranes, which allow natural light to penetrate without excessive heat gain. A properly designed building envelope can support thermal comfort by maintaining stable indoor temperatures, reducing energy loads, and creating a more comfortable environment for occupants. This study examines the building envelope of the South Quarter Dome, which uses ETFE material, focusing on the material's characteristics related to thermal insulation and light transmission to support both thermal and visual comfort for its users.

South Quarter Dome is an example of a building that utilizes ETFE material technology, located at Jl. RA Kartini Kav 8, Cilandak Barat, Cilandak District, South Jakarta City, and was completed in 2019. This study will explore various aspects of the environmentally friendly material ETFE, used as a building envelope material that can optimally respond to environmental conditions to support thermal and visual comfort as well as environmental sustainability.

2. Material and Methods

1.1. Ethylene Tetrafluoroethylene (ETFE) on Building Envelopes

According to Afrianti (2018), the building envelope is one of the elements that encloses a building, such as walls and roofs, whether transparent or opaque, through which a significant amount of thermal energy is transferred [4]. Ethylene Tetrafluoroethylene (ETFE) is a fluorine-based plastic material known for its exceptional technical characteristics. This lightweight material has been known since the 1940s. ETFE (Ethylene Tetrafluoroethylene) is lighter than glass and possesses transparent properties that allow it to channel natural light into the building effectively. Additionally, the natural light entering the room can passively help to warm water [5].
Ethylene Tetrafluoroethylene (ETFE) as a building envelope material makes a significant contribution to both thermal and visual comfort, with the following characteristics:

1. According to Robison (2005) et al., ETFE foil roofing material has a higher rating for insulation with a U-Value of 1.9 W/m²K, compared to single glass at 6.3 W/m²K or double-glazed glass at 3.2 W/m²K [6]. The U-value or transmittance value is a key variable in calculating heat transfer through the building envelope [7] ETFE is also resistant to extreme weather conditions, withstanding temperatures as low as -200°C and as high as 150^{o}C [8]

2. ETFE can represent light smoothly and evenly to reduce uncomfortable light reflections. Its high transparency allows natural light to penetrate maximally into the building, creating a harmonious environment. The dome design using ETFE also supports the creation of a more comfortable space with even temperature distribution.

The performance of ETFE not only enhances the aesthetics of a building but also promotes energy-efficient use, making it suitable for modern architectural projects.

1.2. Termal Comfort

Thermal comfort, according to ISO 7730 (2003), is defined as "a condition of mind that expresses satisfaction with the thermal environment." According to ASHRAE (1989), thermal comfort is a concept aimed at finding personal satisfaction, considered from an empirical perspective. Research by Lippsmeier shows that at a temperature of 26°C, humans begin to perspire and experience reduced endurance [9]. Thermal comfort is influenced by several factors, such as climatic factors, human factors, and physical factors.

The room temperature considered healthy, according to MENKES NO.261/MENKES/SK/II/1998, ranges from 18°C to 26°C. Based on the standards set by SNI 03-6572-2001, the comfort level at temperatures in Indonesia is as follows:

Table 1: According to SNI 03-6572-2001, the thermal comfort standards in Indonesia

Cool and comfortable.	20,5°C TE – 22,8°C TE 24°C TE	Humidity 50%
Optimal comfort.	22,8°C TE – 25,8°C TE 28°C TE	Humidity 70%
Warm and comfortable.	25,8°C TE – 27,1°C TE 31°C TE	Humidity 60%

Source: SNI 03-6572-2001

1.3. Visual Comfort

Hari Widiyantoro et al. (2017:65) state that visual comfort is achieved when visual comfort points have been optimally applied, ensuring alignment between the design and the recommended lighting standards, as well as appropriate light distribution for the room layout ruang. [10].). According to Ners in Anggraini and Susetyo (2016), a person engaged in activities in a space will feel comfortable when their basic needs have been met. [10].

Among the many factors influencing visual comfort, the National Standardization Agency (Badan Standardisasi Nasional) has issued standards for measuring lighting intensity (lux). The standard for lighting intensity measurement is outlined in the SNI 6197:2020 document published by the National Standardization Agency. The recommended average lighting level for lounge areas (such as the function of the space in the SQ Dome) is 100 lux.

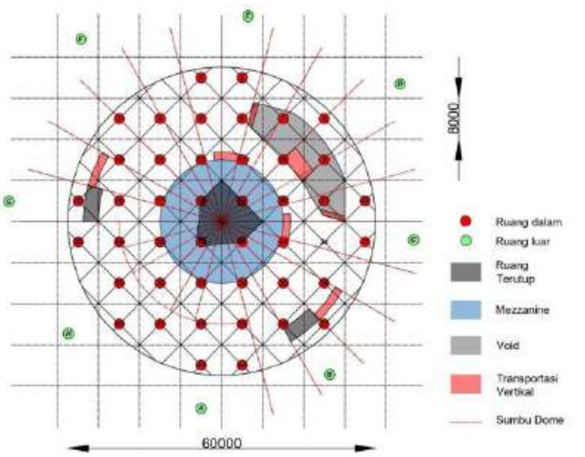
1.4. Method

The method used in this research is a mixed methods approach, which combines both qualitative and quantitative research methods through the collection of secondary and primary data. The author also conducts analysis based on the information obtained, limited to weather climate conditions, documentation, observations, and various sources from literature studies.

1. The quantitative data analysis involves measurements using research instruments such as a digital lux meter and an anemometer at specific points, divided by 8m in each column. The scatter plot diagram shows the relationship between two variables on the x and y axes in the mapping of the South Quarter Dome research object, which has an ETFE building envelope material.

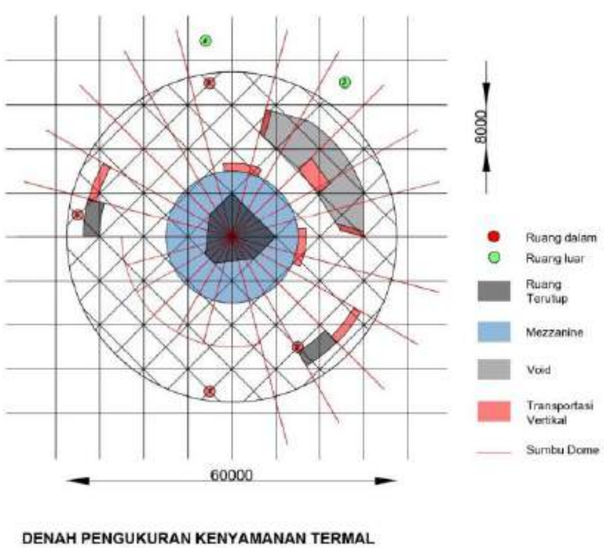
2. The qualitative data analysis involves thematic analysis as the process of mapping the boundaries of the research object, presented in the form of a grid divided every 8m, ultimately resulting in 44 points within the interior of the South Quarter Dome building envelope made of ETFE. This analysis then leads to conclusions in the form of percentages of lighting intensity values and a comparison of temperature values.

The research started in November 2024, involving measurements during the day and afternoon at 44 points in the interior and 6 points in the exterior of the South Quarter Dome, after mapping the area. The selection of these points follows the SNI 7062:2019 guidelines, which require a minimum of 36 measurement points for spaces larger than 100 m².



Source: (Reina,2024)
Figure 1: Light Intensity Measurement Points Floor Plan

Meanwhile, temperature measurement points are located in areas with human activity and those that have heat sources, such as the presence of air conditioning units.



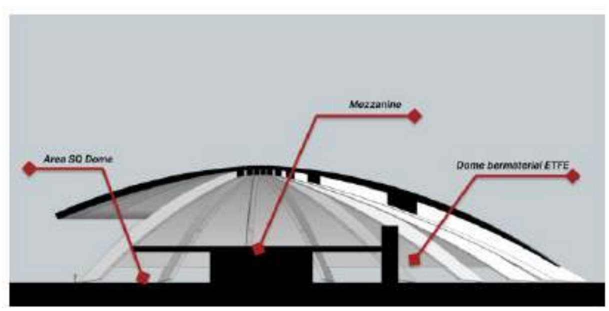
Source: (Reina,2024)
Figure 2: Temperature Measurement Points Floor Plan

3. Results and Discussions

2.1. Location Context

South Quarter is located at Jl. R.A Kartini No. Kav 8, Cilandak Barat, Kec. Cilandak, South Jakarta. It is built on a land area of 7.2 hectares and is divided into several functions and types of building mass, namely SQ Office, SQ Res, and SQ Dome. South Quarter Dome is an area that carries the concept of meet, dine, and hangout, with the building function as a lifestyle mall offering several facilities such as dining places, bookstores, supermarkets, a fitness center, and other amenities. SQ Dome is surrounded by three office towers. The transparent dome shape adorned with traditional Indonesian batik patterns on ETFE material provides optimal lighting during the day. The open area in SQ Dome also becomes an iconic space with a lush atmosphere and numerous seating areas for relaxation.

Source: (Reina,2024)
Figure 3: Representation Model of the SQ Dome Building

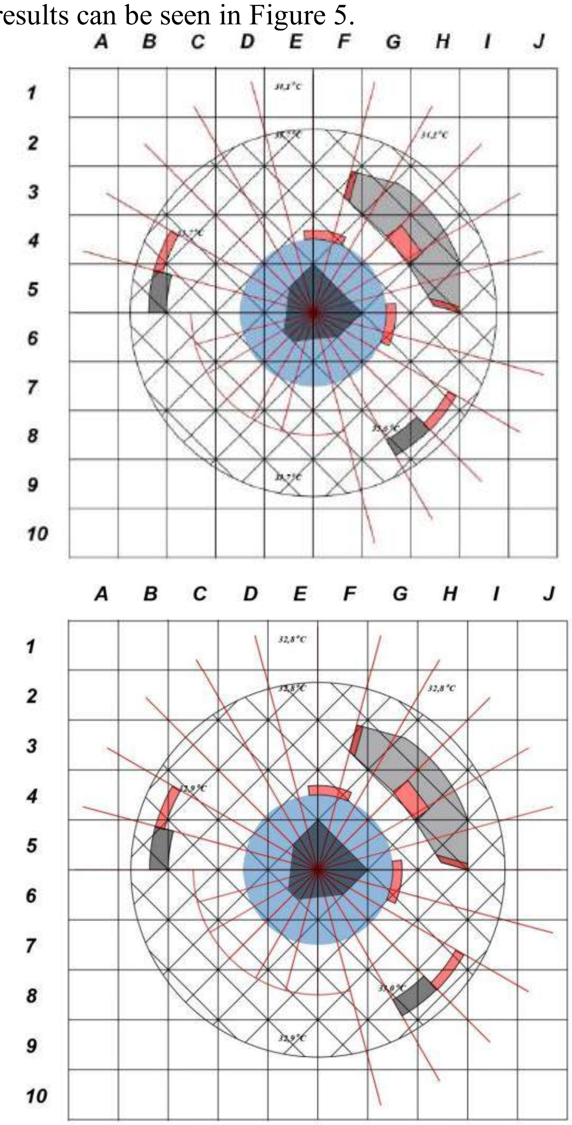


Source: (Reina,2024)
Figure 4: Illustration of the Building Section of the SQ Dome

ETFE (Ethylene Tetrafluoroethylene) material is used on the South Quarter Dome as the covering for the dome-shaped building, featuring openings around it.

2.2. Study of Indoor Temperature Values in the SQ Dome

Air temperature and wind speed measurements were taken using an anemometer at several predetermined points during the mapping process of the South Quarter Dome area. The collected data will be compared with the parameters established in SNI 7061-2019 regarding comfortable working climate conditions for users. The measurement results can be seen in Figure 5.



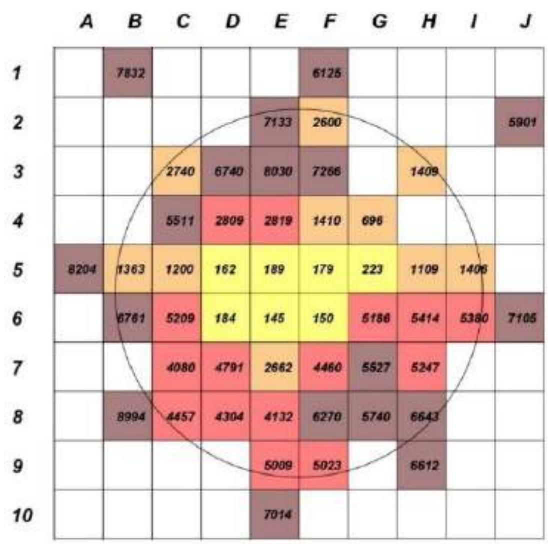
Source: (Reina,2024)

Figure 5: Temperature Measurement Results during the Day (top) and in the Evening (bottom)

After conducting measurements during the day, it was concluded that the highest indoor temperature, which reached 33.7°C, was found in areas E9, B5, and E2. Meanwhile, the outdoor temperature tended to be similar, around 34.1°C, in area H2. Measurements taken in the evening showed that the highest temperature was in the G8 zone, with a temperature of 33°C, while the outdoor temperature was slightly lower at 32.8°C. The results of the measurements indicate that the outdoor temperature was higher than the indoor temperature during the day. The lower outdoor temperature in the evening suggests a change in temperature as sunset approached, with the indoor temperature recorded 0.2°C higher.

2.3. Measurement of Light Intensity Values

The results of the light intensity measurements for the indoor and outdoor spaces of the SQ Dome building can be seen in the following image.



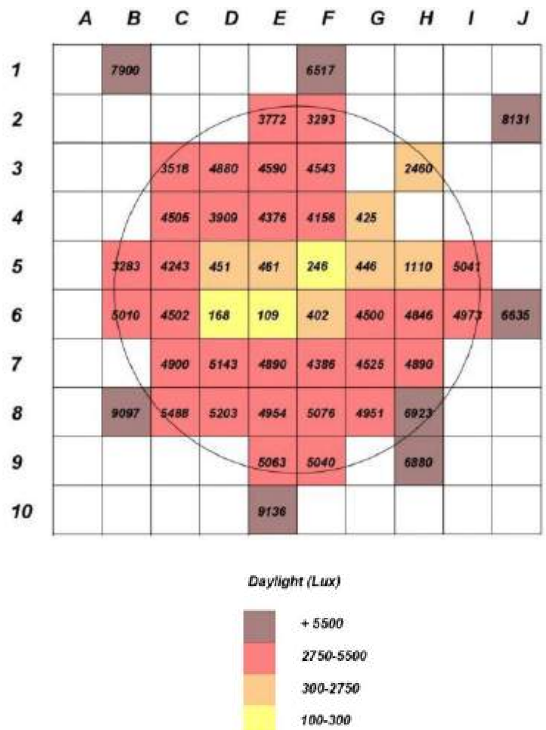


Figure 6: Light Intensity Measurement Results during the Day (top) and in the Evening (bottom)

After conducting light intensity measurements at 44 indoor points and 6 outdoor points, the results can be seen in the scatter plot diagram, which is color-coded within specific lux ranges. It shows that the outermost points, represented by darker colors, indicate a higher level of illumination, while the intensity decreases as you move inward. This suggests that the ETFE material used in the building's envelope influences the amount of light entering the building. The results also include a mapping of the light transmission percentage through the ETFE, which can be seen in Figure 7.

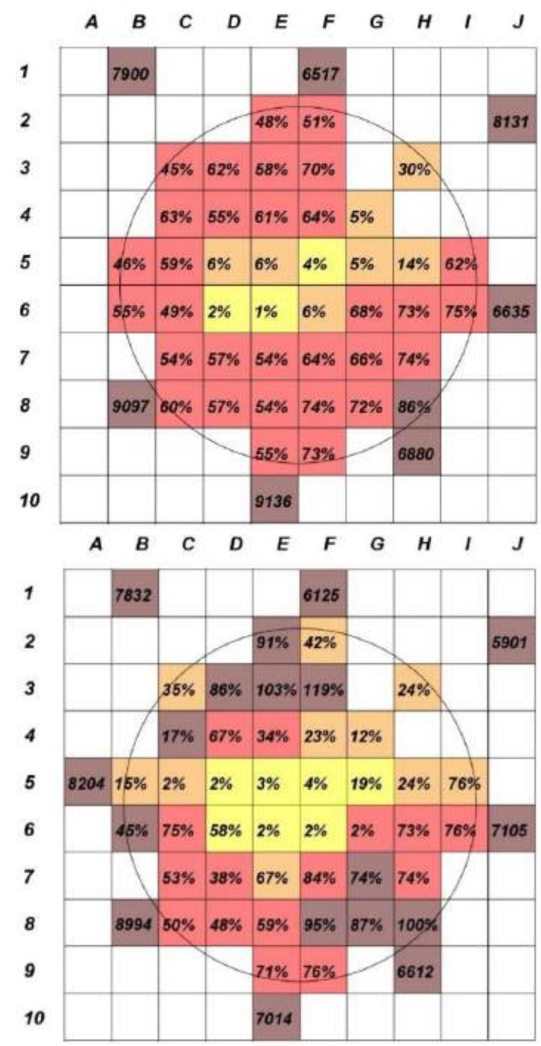


Figure 7: Mapping of Light Transmission Percentage during the Day (top) and in the Evening (bottom)

4. Conclusion

The measurement results of the temperature difference between the indoor and outdoor spaces in terms of thermal comfort, due to the ETFE material as the building envelope of the South Quarter Dome, recorded a difference of 0.4°C. In the evening, the indoor temperature was 0.2°C higher compared to the outdoor temperature. In this regard, further research is needed to understand why the outdoor temperature decrease does not correspond with the decrease in indoor temperature.

The measurement results of light intensity for visual comfort in the indoor space, using the ETFE material as the building envelope of the South Quarter Dome, show a light transmission range varying between 1% and 95%. This measurement indicates that the ETFE material has varying light transmission capabilities depending on the location and time of measurement. The lowest light transmission, with a percentage of 1%, was found in the zone located 32 meters away from the building's envelope. Meanwhile, the highest light transmission, with a percentage of 95%, was found in the zone 24 meters away from the nearest outer point. This demonstrates that the amount of light transmitted is influenced by the distance from the building's envelope.

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