The Openings and Lighting Design Strategies of Primary School in Jakarta

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Abstract. The level of illumination in a room is very important to support the activities that are being carried out in the room. The width of the openings and the side lighting design strategy are things that need to be analyzed to maximize the natural lighting that enters the room without dazzling the eyes, especially in the classroom. This study aims to determine the width of the opening and the side lighting design strategy of an elementary school in Jakarta that can maximize natural lighting without dazzling the eyes based on the level of illumination so that visual comfort standards can be achieved. The method used is to build a building using FormIt software to determine which side of the building gets sun exposure and makes several simulations of the area of openings and several simulations of side lighting design strategies using the Velux Daylight Visualizer 3 software to determine the level of lighting in the room according to the standard lux requirements for educational institutions. From the research results, it can be seen that the width of the opening and the side lighting design strategy of a room affects the level of natural lighting obtained.

Keywords. natural lighting, primary school, side-lighting, jakarta, illumination levels

1. Introduction
Natural lighting is a source of lighting that comes from sunlight. Natural rays have many advantages, besides saving electrical energy, they can also kill germs. Sunlight is a natural resource as renewable energy [1]. Therefore, it is very effective to use sunlight to become natural lighting.

The design of schools by maximizing natural lighting aims to produce harmony between humans and their natural environment. Jamala and Kusumawanto (2010) explains that visual comfort in school buildings is very important in the learning process. Lack of visual comfort can lead to ineffective learning effectiveness and efficiency. The building must be able to adapt to the climatic influences in the area where the building is located.

School is a very basic need for everyone, especially in today's era where education is increasingly prioritized. School is also the second environment where children practice and grow their personalities [2]. One of the most important factors to support students in getting an education is the school building. So, a safe, comfortable, strong, and sturdy building is needed to support academic and non-academic activities and to support the realization of the teaching and learning process. The building...
must be able to withstand any weather conditions so that it can support the activities that take place in it, and provide protection and comfort to its users.

Therefore, this paper aims to determine how wide is the opening and which side lighting design strategy can be used for the school in Jakarta.

2. Literature Review
2.1. Natural Lighting
There are three things to note in natural lighting, namely [3]:

- Shading to keep direct sunlight from entering the room through the openings.
- Arrangement of the location and dimensions of the opening so that the light of the celestial ball can be utilized properly.
- Selection of color and texture of indoor and outdoor surfaces to obtain good reflection (for efficient light attenuation) without dazzling eyes.

Parmonangan Manurung (2012: 17) explains that one of the roles that natural light gives to humans is in terms of comfort. This role is assigned not only inside the building but also outside the building. There are at least two kinds of comfort that are influenced by natural light in humans, namely, visual comfort and thermal comfort. Visual comfort is related to natural light which helps humans access visual information in accessing visual information without disturbing the human visual senses. Visual conditions that are too dark due to lack of light will create discomfort for the visual senses.

Conversely, the excessive level of illumination caused by natural light will also cause discomfort to the visual senses. High levels of light illumination will result in glare and affect visual comfort and can have a negative impact not only on physiology but also on the psychological side of humans. Lack or excess light will make the human eye tire quickly. Eye fatigue can have various adverse effects on humans.

Inadequate lighting is an additional burden for students so that it can disrupt the learning process which in turn can have an impact on health. This is very closely related and absolutely must exist because it relates to the function of the sense of sight, which can affect the level of effectiveness in the learning process.

Natural lighting is a source of lighting that comes from sunlight. Natural rays have many advantages, besides saving electrical energy, they can also kill germs. To get natural lighting in a room, large windows or glass walls are required at least 1/6 of the floor area.

2.2. Natural Lighting System In Buildings
In general, natural light is distributed into the room through side openings (side lighting), openings above (top lighting), or a combination of both. Building type, height, building ratio, and mass arrangement, and the presence of other buildings in the vicinity are considerations for choosing a lighting strategy [4].

Side lighting is the most widely used natural lighting system in buildings. In addition to entering light, it also provides freedom of view, orientation, external and internal connectivity. The position of the window on the wall can be divided into 3, namely: high, medium, low, which is applied based on the needs of the light distribution and the wall system.

Common side lighting design strategies include:

- Single side lighting, openings on one side with strong directional light intensity, the farther the distance from the window the weaker the intensity
- Bilateral lighting, openings on two sides of the building to increase the even distribution of light, depending on the width and height of the room, as well as the location of the lighting openings.
Multilateral lighting, several openings on more than two sides of a building, can reduce glare and contrast, increase the even distribution of light on horizontal and vertical surfaces, and provide more than one main zone of natural lighting.

Clerestories, top windows 210 cm above the sky, are a good strategy for local lighting on horizontal or vertical surfaces. Placing high light openings on the wall can provide a deeper penetration of light into the building.

Light shelves, providing a medium for the window position, separating the glass for the view and the glass for lighting. It can be external, internal, or a combination of both.

Borrowed light, the concept of shared lighting between two adjacent rooms, for example, corridor lighting obtained from the transparent partition of the adjacent room.

Daylight Duct System, a system that collects light by placing a light collector on the outside of the building and a diffuser on the ceiling that provides brilliant natural light to the room below. Sometimes called tubular skylights, light tubes, sun pipes, sun tunnels, and light tunnels.

2.3. Natural Lighting Design Criteria
Concerning the Indonesian National Standard on Procedures for Designing Natural Lighting Systems in Buildings, the following is briefly described [5].

A building with natural lighting during the day can be said to be good if there is enough light entering the room from 08.00 to 16.00 local time and the light distribution is quite even or not dazzling to the eye.

The level of natural lighting in the room can be determined by the level of sky lighting on a flat plane in an open field at the same time.

The comparison of natural lighting in the room and natural lighting on a flat area in an open field is determined by several factors, namely:

- The geometric relationship between the measuring point and the light hole
- The size and position of the light holes
- Distribution of skylight
- The part of the sky that can be seen from the measuring point.

The natural lighting factor during the day is the ratio of the level of illumination at a point from a certain area in a room to the level of illumination in the flat area in the open field. If a room gets the lighting of the sky through light holes in several walls, then each of these walls has a field of light holes.

2.4. Large Standards of Natural Lighting by Space
The minimum light level recommended by the National Standardization Agency for Indonesia should not be less than the lighting level in the table below, namely [6]:

| Room Function | Lighting level (Lux) | Color rendering group | Color temperature |
|---------------|----------------------|-----------------------|------------------|
|               |                      |                       | Warm white      | Warm white      | Warm white |
|               |                      |                       | <3300 K          | 3300 K          | >5300 K    |
| Classroom     | 350                  | 1 or 2                | no               | yes             | yes        |

Table 1. Lux Standards for Educational Institutions (Source: Badan Standardisasi Nasional).
3. Methodology
3.1. Research Methods
The research was conducted using quantitative methods, collecting data such as: data on sunlight, the location of classrooms, and types of openings. From the data obtained, it was analyzed using a simulation. The simulation software used are FormIt and Velux Daylight Visualizer 3. Through the FormIt software, the lighting levels are obtained on all four sides of the building.

Through the Velux Daylight Visualizer 3 software to determine an effective side lighting design strategy to be used in order to maximize natural lighting and not cause glare in the classroom and determine the level of classroom lighting obtained is in accordance with predetermined standards.

4. Result and Discussion
4.1. Simulation
4.1.1 Simulation of Opening Area. The following is the result of a wide analysis of openings that can maximize natural lighting for elementary schools, especially classrooms. Concerning the SNI 6197: 2011 book regarding Energy Conservation in Lighting Systems (2011), the minimum recommended lighting level standard is then entered into the Velux Daylight Visualizer 3 software to determine the most optimal opening area for receiving sunlight. The parameters used in this simulation are the location of the research site, namely in Cempaka Putih Barat Village, Central Jakarta, with an analysis of the level of lighting in a room, then analyzing the area of the building openings per January and April. To determine the most effective building opening area in maximizing natural lighting.

Based on the figure 1 and figure 2 results, it can be seen that the average lighting level at the opening area of 40% obtained in January was 201.2 lux and in April was 160.4 lux.

Based on the figure 3 and figure 4 results, it can be seen that the average lighting level at the 50% opening area obtained in January was 226.6 lux and in April was 170.7 lux.
Based on the figure 5 and figure 6 results, it can be seen that the average lighting level at the 60% opening area obtained in January was 302.8 lux and in April was 227.9 lux.

4.1.2 Simulation of the Lighting Design Strategy. The following are the results of an analysis of side lighting design strategies that can maximize natural lighting without creating glare for elementary schools. By modeling the side lighting design strategy in the book Daylight in Buildings (2005) by Michael D Kroelinger, he made several simulations of side lighting design strategies in the site area using SketchUp software then moved to the Velux Daylight Visualizer 3 software to analyze the most effective side lighting design strategies for receiving sunlight without dazzling the eyes. The parameter used in this analysis is the location of the research site, namely in the Cempaka Putih Barat Village, Central Jakarta. The size of the room used is 64 m² for 28 students in one room with a minimum ratio of class room area of 2 m²/student. To determine the most effective side lighting design strategy for receiving sunlight without dazzling the eyes.

Based on the figure 7 results, it can be seen that the average lighting level using a single side lighting design strategy is 297.8 lux.

Based on the figure 8 results, it can be seen that the average lighting level using the bilateral lighting design strategy is 573.3 lux.
Based on the figure 9 results, it can be seen that the average lighting level using a multilateral lighting design strategy is 1,026.3 lux.

Based on the figure 10 results, it can be seen that the average lighting level using the Clerestories design strategy is 379.6 lux.

Based on the figure 11 results, it can be seen that the average lighting level using the light shelves design strategy is 146.3 lux.

Based on the figure 12 results, it can be seen that the average lighting level using the horizontal daylighting system design strategy is 348.5 lux.

4.1.3 Simulation Natural Lighting. In accordance with the data and analysis of various natural lighting strategies, the type most suitable for use in elementary schools is the Horizontal Daylighting System.

In conducting simulations related to optimal natural lighting in buildings, fixed variables have been determined based on the previous analysis as follows:

- Horizontal Daylighting System orientation facing east.
- Climate adjusted as follows:
  - The climate used as reference is tropical
  - Site position in Central Jakarta : -6.1815° S, 106.8646° E
  - The natural lighting strategy used is the Horizontal Daylighting System which is applied to Home of Pets.

In conducting simulations related to optimal natural lighting in buildings, the independent variables have been determined based on the previous analysis as follows:

- Simulations are carried out with the following timing conditions: 10 AM and 1 PM.
- Simulations are carried out according to the movement of the sun's position (irradiation): March, June, and September
• The following is the position of the camera at the time of shooting related to the simulation

![Camera Position](image)

**Figure 13.** Camera position at the time of shooting (Source: Personal Data Simulation Velux Daylight Visualizer 3, 2021)

**Figure 14.** Horizontal Daylighting Simulation March at 10 AM (Source: Personal Data Simulation Velux Daylight Visualizer 3, 2021)

The average natural lighting in the simulation figure 14 shows the level of illumination on March that meets the criteria and is more than the standard 350 lux for the class.

**Figure 15.** Horizontal Daylighting Simulation March at 1 PM (Source: Personal Data Simulation Velux Daylight Visualizer 3, 2021)

The average natural lighting in the simulation figure 15 shows the level of illumination on March that meets the criteria and is more than the standard 350 lux for the class.

**Figure 16.** Horizontal Daylighting Simulation June at 10 AM (Source: Personal Data Simulation
The average natural lighting in the simulation figure 16 shows the level of illumination on June that meets the criteria and is more than the standard 350 lux for the class.

Figure 17. Horizontal Daylighting Simulation June at 1 PM (Source: Personal Data Simulation Velux Daylight Visualizer 3, 2021)

The average natural lighting in the simulation figure 17 shows the level of illumination on June that meets the criteria and is more than the standard 350 lux for the class.

Figure 18. Horizontal Daylighting Simulation September at 10.00 (Source: Personal Data Simulation Velux Daylight Visualizer 3, 2021)

The average natural lighting in the simulation figure 18 shows the level of illumination on September that meets the criteria and is more than the standard 350 lux for the class.

Figure 19. Simulasi Horizontal Daylighting Bulan Septembert jam 13.00 (Sumber : Data Pribadi Simulasi Velux Daylight Visualizer 3, 2021)

The average natural lighting in the simulation figure 19 shows the level of illumination on September that meets the criteria and is more than the standard 350 lux for the class.

5. Conclusion

Sunlight is a renewable energy that can be used as natural lighting in homes, offices, buildings and schools. Sunlight has a role in humans, which can provide comfort. Comfort in question is visual comfort or thermal comfort. Visual comfort in school buildings is very important in supporting the process of learning activities in schools. Lack of visual comfort level can cause the effectiveness of learning in schools to decrease.
A study of the area of openings and effective side lighting design strategies to be used in order to maximize natural lighting in elementary schools has been carried out and the conclusion shows below.

Based on the simulation results of the analysis of the opening area using the Velux Daylight Visualizer 3 software, the opening area of 60% is the effective opening area to be used to receive sunlight. Because the average lighting level obtained in the opening area is 60% close to the standard lighting level from the National Standardization Agency for classrooms, which is 350 lux.

And based on the simulation results of the side lighting design strategy analysis using the Velux Daylight Visualizer 3 software, an effective design strategy to use in order to maximize natural lighting is the Horizontal daylighting system.

From the results of the study, it can be seen that the level of natural lighting in a building can be influenced by the orientation of sunlight, the opening area and the side lighting design strategy of a building.

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