A Study on External Shading Devices for Reducing Cooling Loads and Improving Daylighting in Office Buildings

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Abstract
This study is aimed at analyzing the impact of effective shading design for office buildings. For shade design, the overheated period for the area in which a target building was located was estimated, the building was configured to be shaded during this period, and a different shading design was applied for each direction. Using this shade design, the daylighting performance and the reduction in cooling loads during the overheated period were evaluated. The daylighting performance was evaluated by employing the daylight factor and useful daylight illuminance (UDI). The results showed a 35% reduction in cooling loads due to the shading device. Regarding the daylight factor, more points were included in a proper daylight factor of 2–5%, which was shown to increase the UDI to 500–2,000 lux.

Keywords: external shading device; cooling loads; daylighting

1. Introduction
1.1 Background
Since the 1990s, countries around the world have recognized the seriousness of climate change and taken considerable measures to prevent global warming. As a part of these efforts, the Kyoto Protocol was established to set emission-reduction targets for each country. The Korean government agreed to reduce Korea's greenhouse gas emissions to 30% by 2020, set building energy-saving reduction targets, and mandate that all new buildings are zero-energy buildings by 2025.

For Korea to achieve its greenhouse-gas reduction target, energy conservation in buildings is considered essential. This is because energy consumption in buildings accounts for 30–40% of the country's total energy consumption. In particular, commercial buildings account for ~35% of building energy consumption, and 50% of building energy is used for heating and cooling. Therefore, reduction of the cooling loads of buildings through shading devices is expected to contribute to the reduction of the overall energy consumption of buildings.

1.2 Study Objectives and Methods
In office buildings, cooling dominates energy consumption. Approximately 50% of cooling loads occur through the building envelope, of which about 50% are generated by solar radiation. Accordingly, the adjustment of solar radiation using external shading devices can significantly reduce cooling loads. In this regard, the first objective of this study is to evaluate the reduction of the cooling loads in an office building that has a high demand for cooling using external shading devices. The second objective of this study is to improve indoor daylighting performance in a glass curtain wall building with a large window-area ratio by installing shading devices. That is, this study aims to improve the visual comfort of room occupants in a building by allowing adequate daylighting indoors while blocking excessive daylight.

The methods used in this study are as follows.
First, the overheated period, which requires shading devices, was estimated, and external shading devices for each direction during this period were designed. Then, the effects of solar-radiation blockage and the overheated percentage of the applied shading device were examined.

Second, the cooling loads of the shading devices were analyzed. To evaluate the cooling loads caused only by blocking the solar radiation, the cooling loads were evaluated, with the exception of the indoor heat emission.

Third, the daylighting performance of the shading devices was investigated. As the building had seven
zones, the daylighting performance for each zone was evaluated using the daylight factor and useful daylight illuminance (UDI).

A flow chart summarizing the research is shown in Fig.1.

![Fig.1. Research Flowchart](image)

### 2. Literature Review

#### 2.1 Review of Existing Literature

Shading devices are mentioned in several books and have been continuously studied. According to a book entitled "Heat, Cooling, Lighting," solar radiation should be blocked during the overheated period of the year, and shading is a key strategy for achieving thermal comfort in summer. A. Green Vitruvius reported that the most effective way to reduce heat gain is to prevent or block solar radiation using shading.

Various findings regarding shading devices are discussed as follows.

Ahmed A. Y. Freewan investigated changes in indoor air temperature and illuminance according to diagonal fins, egg crates, and vertical fins, reporting that a shading device reduced the indoor air temperature by 5% on average. Laura Bellia et al. reported that annual energy savings can be reduced by as much as 20% by changing the length and type of the shading device.

D. Saelensa W. et al. analyzed cooling-energy savings using the ray-tracing method and reported a reduction as large as 20% in some cases. Abdelsalam Aldawoud researched the combination of shading devices and electrochromic glazing, demonstrating that this combination can reduce the solar-heat gain by 40–60%. Gon Kim et al. compared overhangs, blinds, light-shelves, and experimental shading devices. Overhangs reduced the cooling load by 18%. For blinds, the cooling loads according to the slat angle of the blinds were compared and exhibited the largest reduction when the slat angle was 70°. Using light-shelves, the cooling load was reduced by ~20%. Experimental shading devices reduced the cooling load by up to 70%. Nedhal A. et al. analyzed changes in the indoor air temperature by comparing overhangs, louvers, and egg crates, reporting that egg crates yielded the largest reduction in the indoor air temperature and duration of discomfort. Gouri Datta analyzed the thermal performance according to the angle of the louver and claimed that the optimal shade design depends on the region and its weather conditions.

Dilshan Remaz Ossen et al. performed a study to optimize the energy consumption by comparing the total heat gain and natural-light penetration among six types of horizontal shading devices.

Maoyu Ran et al. conducted a study on passive solar shading suitable for the climate by combining solar shading and dehumidification in a hot-humid region.

Jaepil Choi et al. determined the louver design having the best performance by comparing the thermal performances of various louver designs, thereby developing a parametric design methodology.

Previous studies focused mainly on energy savings according to changes in the type and length of shade. In this study, a shading device optimized for the overheated period was designed, and its cooling loads were evaluated.

### 3. Shade Design

#### 3.1 Target Building

As shown in Fig.2., the target building was P’s Green Building, which is located on the Songdo Campus of Yonsei University. It was designed to reduce energy by 0–60% compared with other buildings. It mainly comprised an office, public housing, and a modular building. This study focused on the office.

![Fig.2. Target Building](image)

The office of the target building had large cooling loads because of its curtain wall and indoor heat emission. It was expected to exhibit significantly reduced cooling loads after the application of an external shading device.

#### 3.2 Analysis of Climate in Incheon

Incheon is a coastal city whose coordinates are 37.5°N and 126.6°E. Here, the average annual temperature is 12.1°C; the lowest mean temperature
(-2.1°C) occurs in January, and the warmest mean temperature (25.4°C) occurs in August. The average annual wind speed is 3.4 m/s, and strong winds occur mainly in winter. The average annual relative humidity is ~70%, and the relative humidity reaches 79.7% in summer. Fig.3. shows a graph of the temperature and relative humidity in Incheon.

3.3 Estimation of Overheated Period

The overheated period must be estimated before the shade is designed. This estimation is intended to determine the period in which shade is needed for the design of shading devices. Thus, the shade design should be preceded by the estimation of the overheated period.

To estimate the overheated period, the monthly average temperature of each time zone was determined, and the period when the average temperature exceeded 20°C was considered the overheated period. The overheated period for the region in which the target building was located was estimated as June to September. Fig.4. shows the sun-path diagram for Incheon, where the target building is located, and the image on the right shows the overheated period on the sun path diagram.

3.4 Sun-Path Diagram for Target Building

After the overheated period that requires shade design is estimated, a sun-shade diagram according to each direction of the target building must be prepared. This is because the solar altitude and position vary over time; thus, a suitable shade design is required.

Autodesk's Ecotect program was used to formulate a sun-path diagram for each direction. The sun-path diagram shown in Fig.6. indicates that the shade-design conditions vary according to the direction. The building is in the northwest. In the northeast, southeast, southwest, and northwest, sunlight mainly appears in the morning, from sunrise to ~2–3pm, from ~11am to sundown, and from ~2pm to sundown, respectively.

3.5 Shade-Design Process for Target Building

The length of a horizontal shading device can be calculated using its elevation angle and azimuth angle, as follows:

\[
\tan \Omega = \tan \beta / \cos \gamma \quad \text{and} \quad P_h = \frac{S_h}{\tan \Omega},
\]

where

- \(\tan \Omega\) = solar-shadow angle,
- \(\tan \beta\) = solar-elevation angle,
- \(\cos \gamma\) = solar-azimuth angle,
- \(P_h\) = projected length of shade,
- \(S_h\) = height of window.

In general, shade design is employed to produce shade from 9am to 5pm, when the solar radiation is strong. However, in this study, it produced shade for the duration of the overheated period, as even the time zone with weaker solar radiation affects buildings and increases their cooling loads.

The shade design for each direction was designed according to the meridian altitude with the strongest solar radiation. Using Equation (1) to calculate the length of the horizontal shading device, the lengths in the southeast, southwest, northeast, and northwest were determined to be approximately 1,000, 1,400, 29,500, and 19,150 mm, respectively. In the northeast and northwest, the length was impossible to calculate using the meridian altitude; thus, it was calculated according to sunrise and sundown.

For the overall unity of the shade design, the projected length was limited to 500 mm, and the shade was designed to fit the overheated period using a vertical shading device. The shade design for each direction is shown in Fig.5.
The left image in Fig.6. shows the overheated period before the shade design, and the image on the right indicates the shades according to the shade design shown in Fig.5. In Fig.6., according to the rule of installing/not installing a shading device, an average temperature was derived for each time zone by month, and periods with an average temperature exceeding 20°C were determined to be overheated. Then, the shading device was installed. Therefore, Fig.6. clearly shows the effects before and after installing the shading device according to the overheated period.

### 4. Analysis of Effects of Shade Design

#### 4.1 Effects of Temporary Blockage by External Shading Device

After the shade design is completed, an analysis must be performed to determine the quantity of sunlight that is blocked. Thus, the authors investigated the amount of solar radiation before and after the shading using a software program called Ecotect. For the analysis, virtual grids were created over the window, and the amounts of solar radiation before and after the shading were compared during the overheated period: from June to September. The maximum value represents the value of the grid with the highest solar radiation among several grids, the minimum value represents the value with the lowest solar radiation, and the average indicates the average value for the entire grid.

#### Table 1. Solar-radiation Reduction (Southeast)

|        | Before shading (Wh/m²) | After shading (Wh/m²) | Reduction rate (%) |
|--------|------------------------|-----------------------|-------------------|
| Maximum| 215,687.3              | 204,453.1             | 5.2               |
| Minimum| 215,684.4              | 31,472.4              | 85.4              |
| Average| 215,685.8              | 93,495.2              | 56.7              |

In the southeast (see Table 1.), the maximum, minimum, and average values yielded solar-radiation reductions of 5.2%, 85.4%, and 56.4%, respectively.

#### Table 2. Solar-radiation Reduction (Northeast)

|        | Before shading (Wh/m²) | After shading (Wh/m²) | Reduction rate (%) |
|--------|------------------------|-----------------------|-------------------|
| Maximum| 178,296.1              | 160,638.1             | 9.9               |
| Minimum| 178,293.9              | 34,574.5              | 80.6              |
| Average| 178,295.0              | 97,807.7              | 45.1              |

In the northeast (see Table 2.), the maximum, minimum, and average values yielded solar-radiation reductions of 9.9%, 80.6%, and 45.1%, respectively.

#### Table 3. Solar-radiation Reduction (Southwest)

|        | Before shading (Wh/m²) | After shading (Wh/m²) | Reduction rate (%) |
|--------|------------------------|-----------------------|-------------------|
| Maximum| 205,980.9              | 196,393.2             | 4.7               |
| Minimum| 205,978.7              | 31,617.2              | 84.7              |
| Average| 205,979.8              | 95,231.3              | 53.8              |

In the southwest (see Table 3.), the maximum, minimum, and average values yielded solar-radiation reductions of 4.7, 84.7%, and 53.8%, respectively.

#### Table 4. Solar-radiation Reduction (Northwest)

|        | Before shading (Wh/m²) | After shading (Wh/m²) | Reduction rate (%) |
|--------|------------------------|-----------------------|-------------------|
| Maximum| 183,101.9              | 163,430.9             | 10.7              |
| Minimum| 183,101.4              | 37,848.6              | 79.3              |
| Average| 183,101.6              | 93,076.7              | 49.2              |

In the northwest (see Table 4.) the maximum, minimum, and average values yielded solar-radiation reductions of 10.7%, 79.3%, and 49.2%, respectively.

The overall solar-radiation reduction rate was ~50%. However, this was the radiation on the surface of the glass and not that transmitted into the room. The amount of radiation transmitted into the room varied depending on the transmittance of the glass and was expected to be far smaller.
5. Analysis of Target Building
5.1 Evaluation of Building Energy Performance

The cooling loads were analyzed after an external shading device was applied to the target building. For the analysis, EnergyPlus v8, developed by the U.S. Department of Energy (DOE), was used. In EnergyPlus, the cooling load was analyzed using the Ideal Loads Air System. The cooling load represents the load needed to maintain the set-point temperature in the room. To model the target building, OpenStudio was employed together with a program called Sketchup. A model of the target building is shown in Fig.7.

The window-area ratio of the target building was 60% and was significantly affected by solar radiation. However, the target building was designed to have 60–80% lower energy consumption compared with conventional buildings. The building was represented by 60%- and 80%-energy-saving models, which differed in the configuration of wall layers as well as in airtightness and thermal transmittance (see Table 5.).

The cooling set-point temperature was 26 °C, and the cooling period was set as April to September (Table 6.). The cooling load in the summer months were generated by five elements: the internal solar radiation, external solar radiation, internal heat gain, transmission, and ventilation. However, in this study, the load caused by the internal heat gain and ventilation was excluded in order to examine the effects of the temporarily blockage.

The monthly cooling-load reduction rates are presented in Table 7. Reductions of 66.0%, 45.9%, 32.7%, 30.7%, 25.9%, and 30.8% were observed for April, May, June, July, August, and September, respectively.

The sum of the cooling loads is shown in Fig.8. The total cooling loads were 74,848.0 and 48,582.2 Kwh before and after the shading, respectively. According to these results, solar radiation is a significant factor affecting cooling loads. In internally dominated buildings similar to the target building, shading devices greatly influence cooling-load reduction.

Fig.9. shows a graph of the cooling loads according to the average daily outside temperature before and after the shading. The cooling load according to the average daily outside temperature after the shading was more evenly reduced than that before the shading. The cooling load is estimated by considering the outside temperature, solar radiation, indoor heat emission. However, Fig.9. and Table 8., which indicate the regression equations, shows the results of applying the outside temperature; solar radiation among the outside data of the same period; and indoor heat emission, which was assumed in the simulation to be identical before and after the shading. As a result of the simulation and regression analysis, the reduction of the cooling load after the shading can be predicted.

| Table 5. Energy Configuration |
|-------------------------------|-------------------|-------------------|
| Internal insulation | Vacuum THK20 + Glass THK50 | Glass THK50 |
| Outside insulation | Vacuum THK20 + Glass THK30 | |
| Airtightness | 2.5 ACH @ 50 Pa | 1.0 ACH @ 50 Pa |
| Thermal transmittance | Wall, floor, roof -0.13 (W/m²K) | Wall, roof -0.13 (W/m²K) |
| | Window -1.61 (W/m²K) | Floor -0.12 (W/m²K) |
| | Window -1.21 (W/m²K) | |

| Table 6. Set-point Temperature |
|-------------------------------|-------------------|-------------------|
| Cooling | 26 °C | Apr-Sep |
| Heating | 22 °C | Oct-Mar |

Table 7. Shading Reduction Rates

|            | Before shading (Kwh) | After shading (Kwh) | Reduction Rate (%) |
|------------|----------------------|---------------------|--------------------|
| Apr        | 5681.2               | 1930.9              | 66.0               |
| May        | 11173.0              | 6040.2              | 45.9               |
| Jun        | 16358.6              | 11006.7             | 32.7               |
| Jul        | 14210.7              | 9842.4              | 30.7               |
| Aug        | 16114.4              | 11939.4             | 25.9               |
| Sep        | 11310.1              | 7822.6              | 30.8               |
5.2 Evaluation of Daylighting Performance

5.2.1 Daylight Factor

The target building comprised seven zones. The building in the left side of the atrium was set in the West Zone, and the building in the right side of the atrium was set in the East Zone. The West Zone had four floors, and the East Zone had three floors. The external illuminance was set as 8,500 lux, which indicates overcast sky conditions. Fig.10. shows a graph of the 8,760 h of external horizontal illuminance obtained through the EnergyPlus calculation under 5,000 lux.

In this study, the recommended indoor daylight illuminance was set at 500 lux, in accordance with the illuminance standard of Korean Industrial Standards (KS): KS A 3011, and the proper indoor daylight factor was calculated as 2–5%. Table 10. shows the external illuminance required to yield 500 lux for each illuminance factor, along with the corresponding available daylighting hours and possible ratios. That is, if the indoor daylight factor is 5%, the external illuminance value required to meet the indoor daylight illuminance of 500 lux is 10,000 lux. In addition, as shown in Fig.10., the time at which the external illuminance exceeds 10,000 lux is 3,310 h, which is 70% of 4,730 h, i.e., the total available daylighting time.

Table 9. Daylighting Factor for Each Zone

| DF (%) | 1F East Zone DF | 2F East Zone DF | 3F East Zone DF | 1F West Zone DF | 2F West Zone DF | 3F West Zone DF | 4F West Zone DF |
|--------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1      | BS 19.2 12.6 9.2 7.0 6.0 5.5 5.1 5.3 6.2 9.2 | BS 18.3 9.3 5.4 3.7 3.1 2.8 2.7 2.7 3.1 4.4 | BS 13.5 5.3 3.2 2.4 2.1 2.2 2 2.1 2.5 3.9 | BS 19.9 17.1 13.5 10.6 8.5 7.3 6.7 6.4 6.7 12.2 | BS 18.7 12.9 8.4 6.3 5.2 4.6 4.3 4.4 4.8 8.3 | BS 6.5 6.4 4.7 3.6 3.1 2.8 2.8 2.3 3.7 7.4 | BS 18.3 12.1 7.5 5.2 4.0 3.3 3.2 4.0 6.2 10.1 |
| 2      | AS 10.7 6.0 5.3 4.5 4.2 3.9 3.8 4.1 5.0 8.1 | AS 13.5 5.3 3.2 2.4 2.1 2.2 2.2 2.5 3.9 | AS 7.5 3.7 3.1 2.7 2.5 2.6 2.6 3 3.6 7.1 | AS 9.7 6.1 6.0 5.4 5.0 4.5 4.6 4.5 5.2 11.2 | AS 6.5 6.4 4.7 3.6 3.1 2.8 2.8 2.3 3.7 7.4 |
| 3      | BS 10.7 6.0 5.3 4.5 4.2 3.9 3.8 4.1 5.0 8.1 | BS 13.5 5.3 3.2 2.4 2.1 2.2 2.2 2.5 3.9 | BS 7.5 3.7 3.1 2.7 2.5 2.6 2.6 3 3.6 7.1 | BS 9.7 6.1 6.0 5.4 5.0 4.5 4.6 4.5 5.2 11.2 | BS 6.5 6.4 4.7 3.6 3.1 2.8 2.8 2.3 3.7 7.4 |
| 4      | BS 10.7 6.0 5.3 4.5 4.2 3.9 3.8 4.1 5.0 8.1 | BS 13.5 5.3 3.2 2.4 2.1 2.2 2.2 2.5 3.9 | BS 7.5 3.7 3.1 2.7 2.5 2.6 2.6 3 3.6 7.1 | BS 9.7 6.1 6.0 5.4 5.0 4.5 4.6 4.5 5.2 11.2 | BS 6.5 6.4 4.7 3.6 3.1 2.8 2.8 2.3 3.7 7.4 |
| 5      | BS 10.7 6.0 5.3 4.5 4.2 3.9 3.8 4.1 5.0 8.1 | BS 13.5 5.3 3.2 2.4 2.1 2.2 2.2 2.5 3.9 | BS 7.5 3.7 3.1 2.7 2.5 2.6 2.6 3 3.6 7.1 | BS 9.7 6.1 6.0 5.4 5.0 4.5 4.6 4.5 5.2 11.2 | BS 6.5 6.4 4.7 3.6 3.1 2.8 2.8 2.3 3.7 7.4 |

Table 10. Daylighting Hours

| DF (%) | 1F East Zone DF | 2F East Zone DF | 3F East Zone DF | 1F West Zone DF | 2F West Zone DF | 3F West Zone DF | 4F West Zone DF |
|--------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1      | 50000 857 18.1 | 25000 2123 44.9 | 16667 2741 57.9 | 12500 3096 65.5 | 10000 3310 70.0 | 8333 3460 73.2 | 7143 3568 75.4 |
| 2      | 6250 3644 77.0 | 5556 3730 78.9 |
| 3      | 5000 3779 79.9 |
Table 11. UDI Values in Each Zone

| Zone       | 1F East Zone UDI (%) | 2F East Zone UDI (%) | 3F East Zone UDI (%) | 1F West Zone UDI (%) | 2F West Zone UDI (%) | 3F West Zone UDI (%) | 4F West Zone UDI (%) |
|------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| AS         | 1 m 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | BS 1 m 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | BS 1 m 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | AS 1 m 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 4 m 5 m 6 m 7 m 8 m 9 m 10 m  |
| UDI        | 33.9 40.4 47.6 54.0 59.7 62.6 64.3 65.7 66.1 62.4  | 37.1 52.6 63.8 68.4 70.3 70.8 71.3 71.4 72.5 75.2  | 39.9 64.0 69.8 71.4 71.5 71.0 70.2 69.9 73.2 79.5  | 35.1 47.5 65.9 73.5 73.5 73.4 73.4 73.6 73.4 73.6  | 37.0 47.3 65.7 75.2 77.8 78.6 78.4 78.3 59.3 49.1  | 68.6 72.3 78.9 79.7 78.9 79.1 78.6 79.1 73.1 69.0  | 73.7 79.4 79.6 79.7 78.4 78.3 76.2 67.1 46.9 39.1  |
| 1F         | 1 m 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 1 m 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m  | 4 m 5 m 6 m 7 m 8 m 9 m 10 m  |
| West Zone  | 74.8 76.5 79.8 80.2 78.6 79.1 78.6 79.1 73.1 69.0  | 74.8 76.5 79.8 80.2 78.6 79.1 78.6 79.1 73.1 69.0  | 74.8 76.5 79.8 80.2 78.6 79.1 78.6 79.1 73.1 69.0  | 35.6 44.1 59.8 67.4 70.5 65.3 56.8 53.8 42.5 34.4  | 35.6 44.1 59.8 67.4 70.5 65.3 56.8 53.8 42.5 34.4  | 68.8 73.2 73.4 77.3 77.6 70.5 63.3 57.1 46.5 36.4  | 68.8 73.2 73.4 77.3 77.6 70.5 63.3 57.1 46.5 36.4  |

5.2.2 UDI

UDI is a daylighting-performance indicator based on annual weather data and an evaluation method proposed by Mardaljevic and Nabil in 2005. It attempts to set a useful indoor-illuminance range with regard to the building energy and occupants, as well as to analyze the quantity of indoor daylight illuminance appearing within this range during annual working hours (08:00–18:00) according to the weather data. The illuminance range is classified into four groups. An illuminance less than 100 lux indicates a lack of daylighting and hence the need for artificial lighting. An illuminance of 100–500 lux shows efficiency but must be supplemented by artificial lighting. An illuminance of 500–2,000 lux does not cause discomfort, and in this case, daylighting alone is sufficient for maintaining indoor daylight illuminance. An illuminance greater than 2,000 lux causes occupants to experience visual and thermal discomfort. In this study, 100–2,000 lux was set as the UDI range.

Table 11 shows the UDI values in each zone. The indoor daylight illuminance was analyzed for working hours (08:00–18:00) in consideration of the occupancy time of the office. The percentage (%) represents the UDI value, which ranged from 100 to 2,000 lux within the full UDI value of each point. For example, if the UDI value before the shading was 33.9% at the 1-m point in the 1F East Zone, the UDI value after the shading was 42.8%, which indicates an increase of ~26%.

The UDI value of the 1–3-m point near the external windows significantly increased because the shading device blocked excessive solar radiation. Overall, the UDI value increased because of the shading device, except for a few points.

6. Conclusion

In this study, the design and effects of an effective external shading device for an office building were examined. The reduction in cooling loads due to the blockage of solar radiation was also evaluated.

For the design of the external shading device, the authors first calculated the average monthly temperature for the region where a target building was located. The period when the temperature exceeds 20°C was denoted as the overheated period, and the building was configured to be shaded during this period. A shading device was designed to differ depending on the direction of the target building, and its effects were evaluated by dividing them into the overshadowing percentage and the effect of the solar-radiation blockage due to the shading device.

In the case of the cooling load due to the external shading device, the indoor heat emission was excluded in order to evaluate the reduction in the cooling loads caused only by blocking solar radiation. The results indicated a 35.1% reduction in the total cooling load.

Regarding the daylighting achieved using the external shading device, more points were included in the proper daylight-factor range of 2–5%, and the range of the UDI increased. On the other hand, the illuminance greater than 2,000 lux, which causes visual and thermal discomfort for occupants, was reduced.

Previous studies compared cooling loads mainly according to the type and length of shading devices. In contrast, we estimated the overheated period of the target region and designed a device to shade the building only during that period. Accordingly, a shade design optimized for the region was implemented. The shading performance is expected to vary among regions, and the findings from this study will be used as reference data for the design of optimal shading devices suitable for other regions.

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