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Reduce CO2 Emissions Using Double Skin Façade in Smart & Green Learning Center UGM Promoting Sustainable Building

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Abstract

The Smart & Green Learning Center is a tower building that offers coworking spaces on both its east and west sides. The objective of this study is to explore the impact of a double skin façade on heat generation and CO_2 gas emissions in co-working spaces. To achieve this, the IES Virtual Environment software simulation method was employed. The monthly average heat gain without the use of a double skin façade ranged from 19 to 21.9 MWh, while the same metric with a double skin façade was between 14.1 and 16.1 MWh. This resulted in a decrease of 4.9 MWh (25.79%) for the lowest monthly average heat gain and a decrease of 5.8 MWh (26.48%) for the highest. Moreover, the use of a double skin façade led to a reduction in CO2 gas emissions by 20.7% to 21.1% at the Smart & Green Learning Center.

INTRODUCTION

According to the Nationally Determined Contribution (NDC) of the Indonesian government, it aims to decrease its CO2 emissions target from 29 percent in 2016 to 31.89 percent through its efforts and from 41 percent to 43.20 percent with international assistance by 2030 (G20 Summit, 2022). To support this commitment, the field of architecture is exploring various passive design strategies for buildings. Among these strategies, this research will focus on the use of double skin façades in buildings. The SGLC building is an eleven-story lecture building with one basement. This building functions as a learning center within the Faculty of Engineering UGM which aims to increase the capacity and ability of academic community resources individually and institutionally as well as to develop competence. This building is used as a classroom, general office-learning and innovation management (deanery), learning space, meeting room/conference room, open public area, and co-working space.

If we observe the SGLC building, we can find that this building uses a double skin façade on several sides of the building mass. There are at least three types of double skin façade applied to SGLC. An investigation was conducted to evaluate the potential reduction in heat gain and CO2 emissions that could be achieved by applying a double skin façade.

SGLC buildings generally have a typical floor plan of 8 floors. The composition of the SGLC building mass extends from east to west. On the east and west sides of each floor, there is a communal space (co-working space). In this communal space, there are still quite large openings facing east and west, so that at certain hours it is still possible for the room to receive excess heat. This situation will increase the cooling load and disrupt the thermal comfort of the building. In the SGLC building, there is a double skin façade in several zones outside of the communal space. It is necessary to carry out thermal investigations in these communal spaces so that we can determine the effectiveness of using double skin façades in terms of building heat gain and reducing CO2 emissions.

The communal/co-working space has an opening on the side of the room that is exposed to direct solar radiation. The east side can be exposed to direct sunlight in the morning. Although there is a site that is blocked by the stairwell as a buffer zone referring to Figure 1. Meanwhile, the west side can be exposed to direct sunlight in the afternoon. This situation will increase the room temperature and allow thermally uncomfortable situations, especially during critical hours when sunlight can directly enter the room. There is a double skin façade on the east and west sides of the SGLC which needs to be further investigated for its effect on reducing heat gain from the room when compared to the situation without a double skin façade.

Fig 1. Co-working Space in SGLC Building
Source: Greenship Recognition Design Session NB VI.2

Fig. 2. Communal Space (co-working space) on the East and West Sides
Source: Author

Fig. 3. Double Skin Façade in East Side of SGLC
Source: Author

This research aims to reveal how much influence the double skin façade has on the heat gain that occurs in communal spaces / co-working spaces. In the end, the efficiency of reducing CO_2 emissions due to the use of double skin façade can be reported. It is hoped that this research can contribute ideas about the appropriate use of double skin façade to reduce CO_2 emissions following the Indonesian government's commitment to reduce CO_2 emissions to 43.2% with global assistance. The objective is to facilitate the transition towards sustainable building practices for the benefit of the Indonesian populace.

The product of architectural design and urban planning in terms of Matsufuji theory (T = W – D) is T (Throughput) should be in maximum value. To achieve this condition, W (welfare) in the area must be maximized, where safety, relief, health, comfort, and sense should be sufficient. On the other hand, the results of urban design must have as little impact as possible on environmental damage (D) (Matsufuji in Kusumawanto, 2021).

An urban design work that has great welfare value, but causes great environmental damage, then the work will reflect a small throughput. This kind of condition is considered not to meet the rules of architecture and green area design. Likewise, urban design works with a small impact on environmental damage but does not produce much welfare in the area and surrounding environment, also not fulfilling the greenness rule (Matsufuji in Kusumawanto, 2021).

Several studies have reported in the field of energy savings and temperature reduction for the use of double skin facades in buildings. The decrease in temperature due to the use of double skin facades was reported to be down to 3.47°C in a studio room in Bandung, West Java (Maknun et al, 2020). The use of various types of double skin facades can minimize energy consumption by up to 60-80% (Mostafa. M.S. Ahmed, et al, 2016). The use of double skin facades can reduce overall energy consumption by up to 68.64% in Surabaya (Kurniansyah, et al, 2016). The implementation of the designed Ventilated Double Skin Facade allows energy savings more than 40% (Lahayrech, et al, 2022). The use of Phase Change Material can increase indoor thermal comfort and reduce temperature by up to 7.34% compared to rooms without double skin facade with Phase Change Material. However, there is no specific research related to the use of double skin facade to reduce CO_2 emissions. Therefore, this research still really needs to be carried out.

METHODS

The research will utilize a simulation method through IES Virtual Environment software to assess the impact of a double skin façade on heat gain and reducing CO_2 emissions in the SGLC building. The software data will be analyzed to determine the effectiveness of this approach on the building, located in the Faculty of Engineering at UGM. Data was collected from a simulation process using IES Virtual Environment 2019 software, based on the geometric shape of the SGLC spaces. The simulation will be carried out with and without a double skin façade to ensure accurate comparisons.

Once the simulation process is complete, the resulting data will be analyzed through a variety of methods and tools, including dialogue with the IES Virtual Environment 2019 software. The initial phase of this project involves preparation, designing the research, selecting data collection methods, and planning how to analyze the research findings. It also involves review of existing literature and creating a comprehensive research implementation plan.

Next, we move to the simulation phase. During this stage, we create a three-dimensional model of the SGLC building using AutoCAD software. Then, we use IESVE software to generate a detailed drawing. Finally, we conducted a simulation using IES VE 2019 software to evaluate the performance of the building.

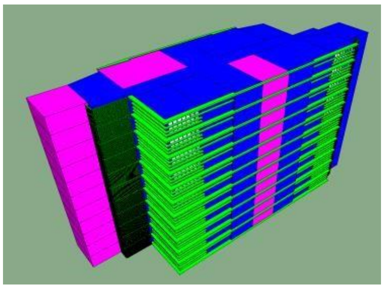

Fig. 4. IESVE Modelling
Source: Author

The next phase is data collection. During this phase, research data is collected and organized into groups. The last phase is analysis and results. This stage is the heart of the research process. The collected data is integrated as a whole to reveal meaning and important conclusions for the research. At this stage, significant research findings are expected to emerge.

Meteonorm software provides location data, specifically weather data for Yogyakarta, spanning a year. Assumptions for the building's thermal envelope value are based on commonly used empirical figures. For brick walls, a U-value of 2.55 Watt/m^{2}K is utilized, while stop-sol glass with a U-value of 5.7 Watt/m^{2}K and a shading coefficient of 0.5 is chosen for the glass, consistent with SGLC's glass. The simulation is conducted using the IES VE's Apache application, a thermal dynamic calculator. The analysis examines the impact of floor height on each co-working space, the location of each co-working space on each floor plan, and the effect of the double skin façade.

Fig. 5. SGLC Building Modelling
Source: Author and IESVE

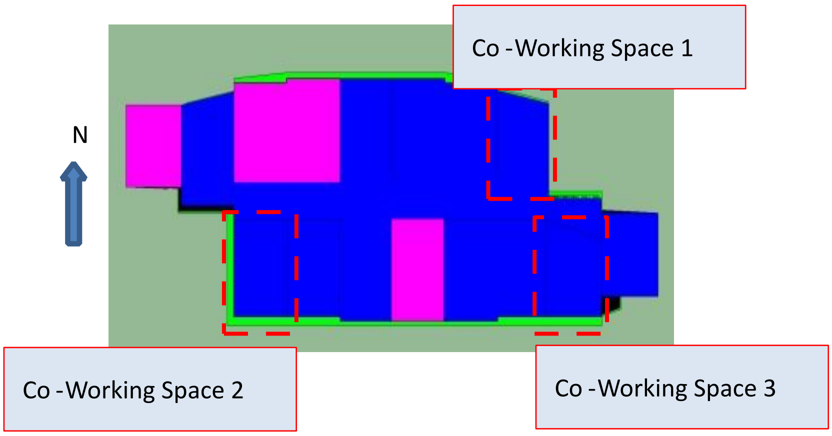

Fig. 6. Co-Working Space Location
Source: IESVE

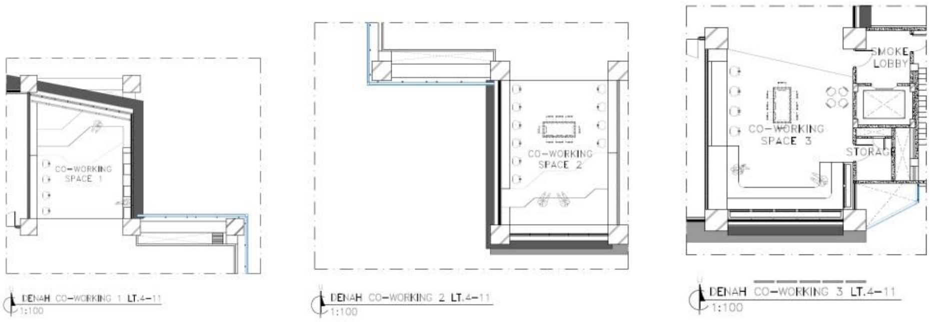

Fig. 7. Co-Working Space 1, 2, and 3 Layout
Source: Author

The co-working space in the SGLC building spans across floors 4 to 11, located on the east and west ends. The layout is repeated throughout these floors, with co-working space 1 situated on the northeast side, co-working space 2 on the west side, and co-working space 3 on the southeast side. A schematic representation of this can be found in Figure 6. In the simulation scenario, we will be analyzing the room under basic conditions, without the use of a double skin façade, as well as using a double skin façade. We will also be taking into account the state of solar radiation (heat gain) and solar conduction (conduction gain) in the room. From there, we will determine the extent of the reduction in CO2 emissions.

When investigating the use of double skin facades on SGLC buildings, it's important to note that they can help reduce CO2 emissions. This reduction is due to a decrease in the "damage" value in the equation, which, in turn, leads to an increase in the "throughput" value. This decrease in "damage" is primarily caused by the significant reduction in electrical energy consumption from the double skin facade's ability to decrease cooling loads within a room.

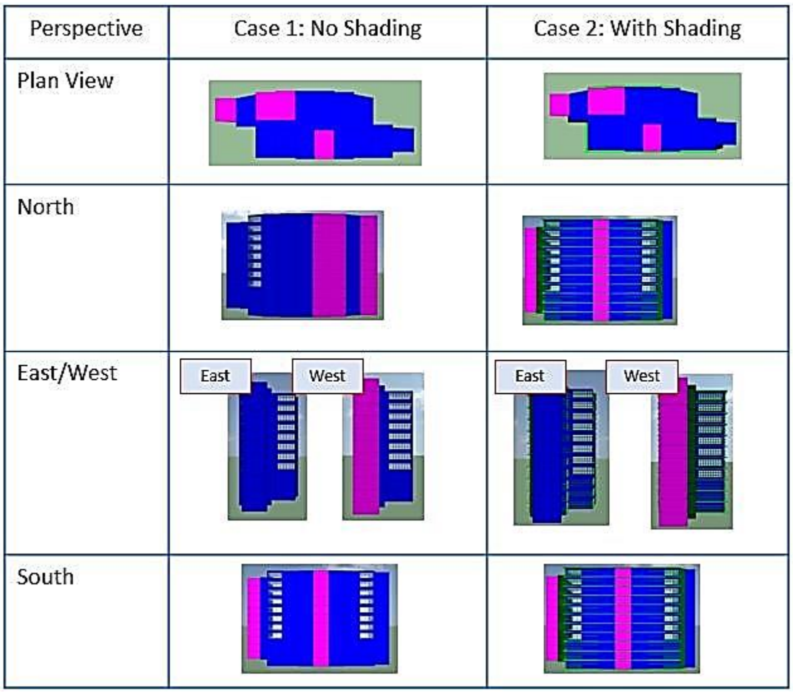

Fig. 8. Stimulation Scenario
Source: Author

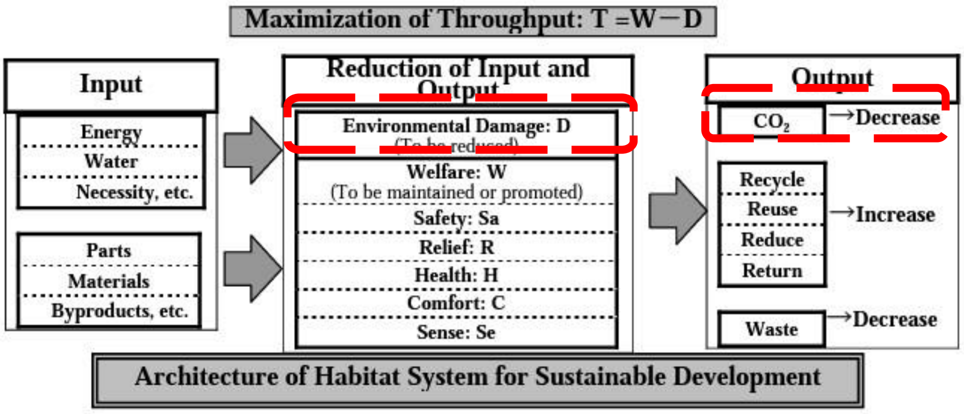

Fig. 9. Sustainable Habitat System Theory
Source: Assessment Concept of Architecture of Habitat System for Sustainable Development

RESULTS AND DISCUSSION

Effect on Elevation

Initially, an assessment was conducted on the floor height's elevation variable, specifically in the co-working spaces situated on levels 4 to 11 of the Smart and Green Learning Center establishment.

In circumstances where a double skin façade is not present, the monthly heat gain for the co-working spaces located on floors 4 through 10 is consistently within the range of 2.35 MWh to 2.7 MWh. Conversely, the co-working space situated on the 11th floor experiences a slightly elevated monthly heat gain range of 2.5 MWh to 2.9 MWh. This disparity can be attributed to the fact that the 11th floor receives heat from the roof directly above it.

The co-working spaces on the 4th through 10th floors of the building with a double skin façade exhibit a monthly heat gain within the range of 1.73 MWh to 1.97 MWh. Conversely, the co-working space on the 11th floor experiences a higher monthly heat gain, ranging from 1.95 MWh to 2.3 MWh, attributable to the heat from the roof above it. Through the implementation of a double skin façade, the co-working spaces on floors 4-10 observe a reduction of 0.62 MWh and 0.73 MWh in their lowest and highest monthly heat gain, respectively. Similarly, the 11th floor experiences a decrease of 0.55 MWh and 0.6 MWh in their lowest and highest monthly heat gain, respectively. However, it's important to note that the double skin façade has no bearing on the heat gain experienced in the co-working space in relation to the variable floor elevation within the SGLC building.

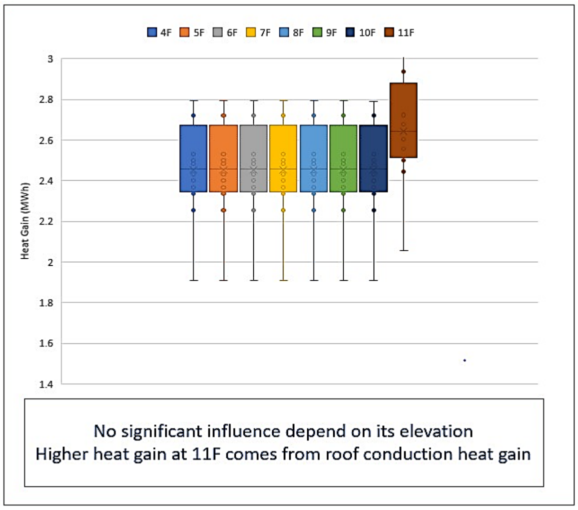

Fig. 10. The Monthly Heat Gain Data Without Shading
Source: IESVE Data Result

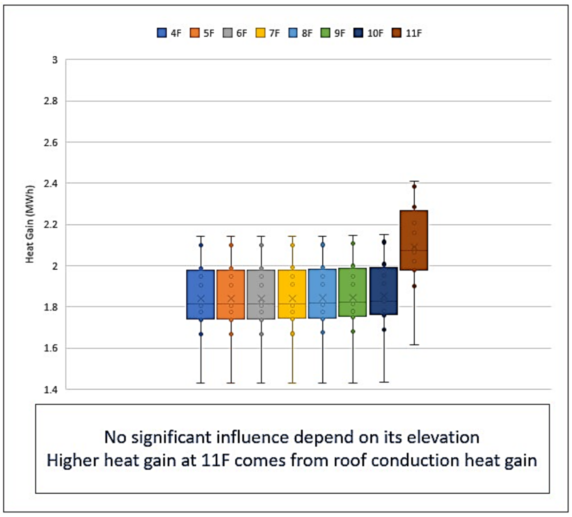

Fig. 11. The Monthly Heat Gain with Shading Scenario
Source: IESVE Data Result

Effect on Room Location

The SGLC building offers co-working spaces on both the east and west sides of each floor, from the fourth to the eleventh floor. Co-working space 1 is situated on the east side of the northern section of the SGLC corridor, while co-working space 2 is located on the west side, south of the corridor. Additionally, co-working space 3 can be found on the eastern side, south of the SGLC corridor.

In conditions without a double skin façade, the lowest monthly solar heat gain received at co-working space 1 is 4.7 MWh, while the highest solar heat gain is around 6.2 MWh. In co-working space 2 the monthly solar heat gain received was the lowest in the range of 4.9 MWh and the highest was in the range of 5.7 MWh. In co-working space 3 the monthly solar heat gain received was the lowest in the range of 2.05 MWh and the highest was in the range of 2.8 MWh.

In conditions without a double skin façade, the lowest monthly conduction heat gain received at co-working space 1 is 2.2 MWh, while the highest conduction heat gain is around 2.8 MWh. In co-working space 2 the monthly conduction heat gain received is the lowest in the range of 2.4 MWh and the highest is in the range of 3.0 MWh. In co-working space 3, the monthly conduction heat gain received is the lowest in the range of 1.5 MWh and the highest is in the range of 1.9 MWh.

In conditions without a double skin façade, the lowest total monthly heat gain received in co-working space 1 is 6.9 MWh, while the highest total heat gain is in the range of 9.0 MWh. In co-working space 2, the lowest total monthly heat gain received was in the range of 7.3 MWh and the highest was in the range of 8.7 MWh. In co-working space 3, the lowest total monthly heat gain received was in the range of 3.55 MWh and the highest was in the range of 4.7 MWh.

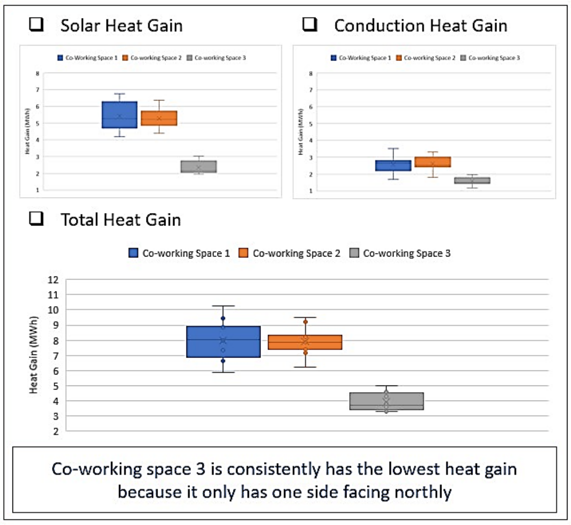

Fig. 12. The Monthly Heat Gain Without Shading Scenario
Source: IESVE Data Result

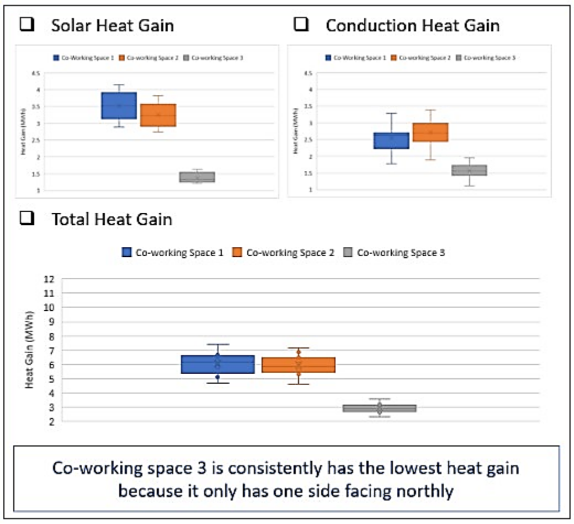

Fig. 13. The Monthly Heat Gain 2ith Shading Scenario
Source: IESVE Data Result

In the case of using a double skin façade, the lowest monthly solar heat gain received at co-working space 1 is 3.1 MWh, while the highest solar heat gain is around 3.9 MWh. In co-working space 2 the monthly solar heat gain received was the lowest in the range of 2.9 MWh and the highest was in the range of 3.55 MWh. In co-working space 3 the monthly solar heat gain received was the lowest in the range of 1.3 MWh and the highest was in the range of 1.5 MWh.

In the case of using a double skin façade, the lowest monthly conduction heat gain received at co-working space 1 is 2.2 MWh, while the highest conduction heat gain is in the range of 2.7 MWh. In co-working space 2 the monthly conduction heat gain received is the lowest in the range of 2.4 MWh and the highest is in the range of 3.0 MWh. In co-working space 3, the monthly conduction heat gain received is the lowest in the range of 1.4 MWh and the highest is in the range of 1.7 MWh.

In the case of using a double skin façade, the lowest total monthly heat gain received in co-working space 1 is 5.3 MWh, while the highest total heat gain is in the range of 6.6 MWh. In co-working space 2, the lowest total monthly heat gain received was in the range of 5.3 MWh and the highest was in the range of 6.55 MWh. In coworking space 3, the lowest total monthly heat gain received was in the range of 2.7 MWh and the highest was in the range of 3.2 MWh.

Co-working space 1 experiences a relatively high solar heat gain value, ranging from 6.9-9 MWh without a double skin facade, but decreasing to 5.3-6.6 MWh with one. This room features two sizable openings to the east and north. Similarly, co-working space 2 also has a significant solar heat gain, ranging from 7.3-8.7 MWh without a double skin facade, but decreasing to 5.3-6.55 MWh with one. This is due to the room's two openings to the south and west. In contrast, co-working space 3 experiences a lower total heat gain without a double skin facade, ranging from 3.55-4.7 MWh, but decreasing to 2.7-3.2 MWh with one. This room only has one opening to the south.

Effect of Double Skin Façade (Shading)

The following figure presents the effect of using a double skin façade on the results of solar heat gain, conduction heat gain, and total heat gain. The data is presented in figure form which describes the condition of the co-working space without using a double skin façade or using a double skin façade.

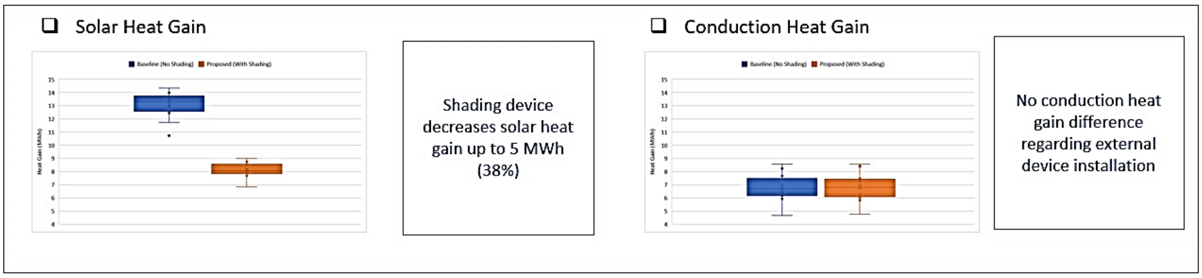

Fig. 14. The Monthly Solar Heat Gain and Conduction Heat Gain
Source: IESVE data Result

Typically, co-working spaces experience a monthly solar heat gain of approximately 12.5 to 13.9 MWh. However, implementing a double skin facade can lower this range to 7.9 - 8.7 MWh. Additionally, the monthly conduction heat gain ranges from 6.1 - 7.7 MWh, regardless of whether or not a double skin facade is utilized.

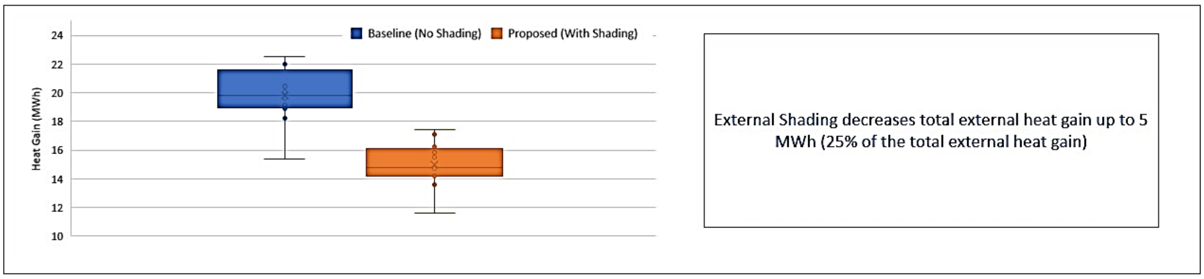

Fig. 15. The Monthly Heat Gain No Shading Scenario vs. with Shading Scenario
Source: IESVE Result Data

The average total monthly heat gain without using a double skin facade is in the range of 19 - 21.9 MWh. Meanwhile, the average total monthly heat gain obtained by using a double skin facade is in the range of 14.1 – 16.1 MWh. The amount of solar heat gain can vary depending on whether or not a double skin facade is used. Without it, the range is between 12.5-13.9 MWh, while with it, the range is 7.9-8.7 MWh. When utilizing the double skin facade, the lowest monthly solar heat gain saw a decrease of 4.6 MWh or 35.66%. The highest monthly solar heat gain experienced a decrease of 5.2 MWh or 59.77%.

The monthly average heat gain from conduction ranges between 6.1 - 7.7 MWh for co-working spaces, regardless of whether they have a double skin facade or not. Based on this data, it appears that implementing a double skin facade does not effectively reduce heat gain from conduction in co-working spaces. The monthly average heat gain ranges from 19 to 21.9 MWh without a double skin facade. However, using a double skin facade reduces this range to 14.1 - 16.1 MWh. This represents a decrease of 4.9 MWh or 25.79% for the lowest total monthly average heat gain and a decrease of approximately 26.48% or 5.8 MWh for the highest total monthly average heat gain.

Average Monthly Heat Gain

The presentation of all monthly data is intended to display the monthly average of heat gain in co-working spaces both in terms of solar heat gain and conduction heat gain. Apart from being presented for each month, the data is also presented based on conditions with and without a double skin façade. By utilizing monthly average heat gain information, we can effectively demonstrate the state of the co-working space in relation to the mean values of solar heat gain (radiation), conduction heat gain, and total heat gain for each month of the solar radiation year. This data is presented under two conditions: one without the application of a double skin façade and the other with a double skin façade. This facilitates easy comparison between the two sets of data.

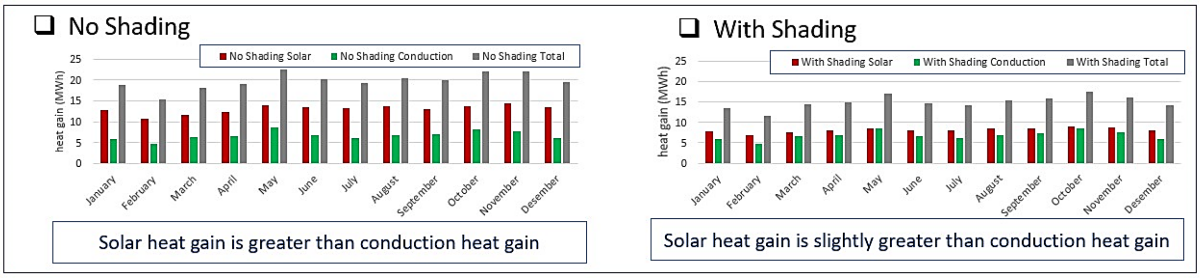

Fig. 16. Monthly Average Heat Gain
Source: IESVE Data Result

By carefully analyzing the monthly average heat gain data, it becomes evident that when a double skin façade is not utilized, solar heat gain results in greater heat gain than conduction. Conversely, when a double skin façade is employed, solar heat gain leads to a slightly higher heat gain than conduction.

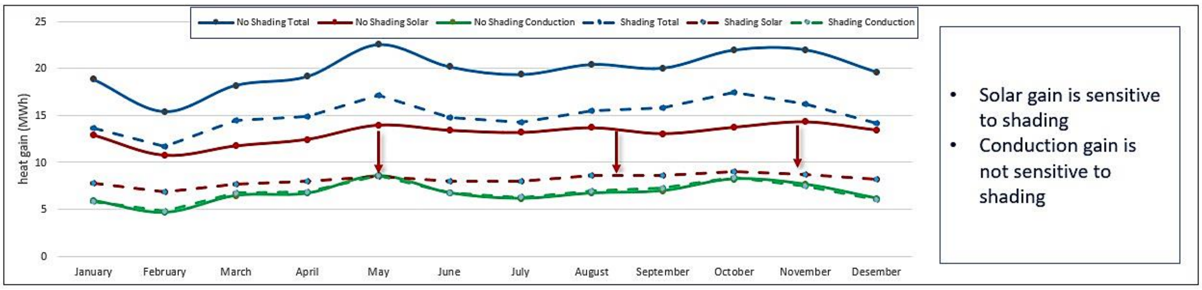

Fig. 17. Monthly Average Heat Gain No shading vs. with Shading Comparison
Source: IESVE Data Result

The implementation of a double skin façade greatly impacts solar heat gain, as evidenced by the monthly solar gain values. Comparing the situation without a double skin façade (no solar shading) to the situation using one (with solar shading), there is a significant difference in the monthly average value. The graph depicts this comparison with a red line for conditions without a double skin façade and a dotted red line for those with one. The difference in value amounts to approximately ± 5 MWh.

In co-working spaces, the impact of double skin façade on conduction heat gain appears to be negligible. This is evidenced by the comparable monthly conduction heat gain values observed in environments without a double skin façade (as indicated by the no shading conduction graph), versus those with a double skin façade (as indicated by the shading conduction graph). The employment of a double skin façade is proven to significantly reduce the average monthly heat gain as compared to not using one. This is illustrated in the form of a blue graph (unshaded) versus a dotted blue graph (with solar shading), showing a difference of approximately ±5 MWh.

Reducing CO2 Emissions Due to the Use of Double Skin Façade

Once we have gathered the necessary information on heat gain reduction, we can analyze the data to generate energy consumption statistics for the SGLC building's co-working area. It is evident from the data presented that the use of a double skin facade has resulted in a noteworthy reduction in energy usage on a monthly basis.

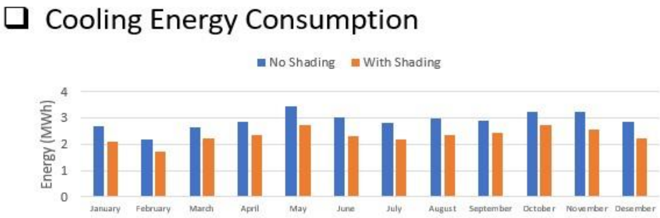

Fig. 18. Cooling Load Energy Consumption
Source: IESVE Data Result

In cases where a double skin façade is not utilized, the energy consumption peak of 3.5 MWh is observed in May. However, if a double skin façade is utilized, energy consumption in May drops to 2.7 MWh, resulting in an energy consumption reduction of 0.8 MWh this month. Conversely, the lowest energy consumption of 2.1 MWh is recorded in February. When a double skin façade is applied, energy consumption in February decreases to 1.8 MWh, resulting in an energy consumption reduction of 0.3 MWh in February. From this data, it can be concluded that utilizing a double skin façade can significantly optimize energy consumption.

When analyzing data on building energy consumption, it was found that utilization of double skin façade resulted in a reduction of energy consumption in the highest consumption month (May) by 0.8 MWh, which constitutes a decrease of approximately 22.9%. Similarly, in the month with the lowest energy consumption (February), the use of double skin façade resulted in a reduction of energy consumption by 0.3 MWh, or around 14.3%.

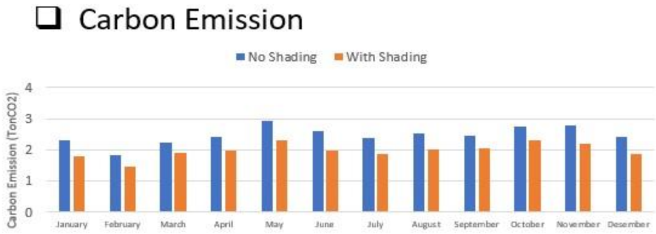

Fig. 19. CO2 Emission
Source: IESVE Data Result

When a double skin façade is not utilized, the CO2 gas emissions reached their peak in May at 2.9 tons. However, implementing a double skin façade resulted in a decrease of 0.6 tons of CO2 gas emissions in May, bringing the total to 2.3 tons. On the other hand, February recorded the lowest CO2 gas emissions at 1.9 tons, which further decreased to 1.5 tons with the use of a double skin façade. This indicates a reduction of approximately 0.4 tons in CO2 gas emissions during February.

When examining CO2 gas emission data, we observed a reduction in emissions of 0.6 tons or approximately 20.7% with the use of double skin façade, compared to the month with the highest CO2 gas emissions (May). Similarly, in the month with the lowest CO2 gas emissions (February), the use of double skin façade resulted in a decrease of 0.4 tons or roughly 21.1%.

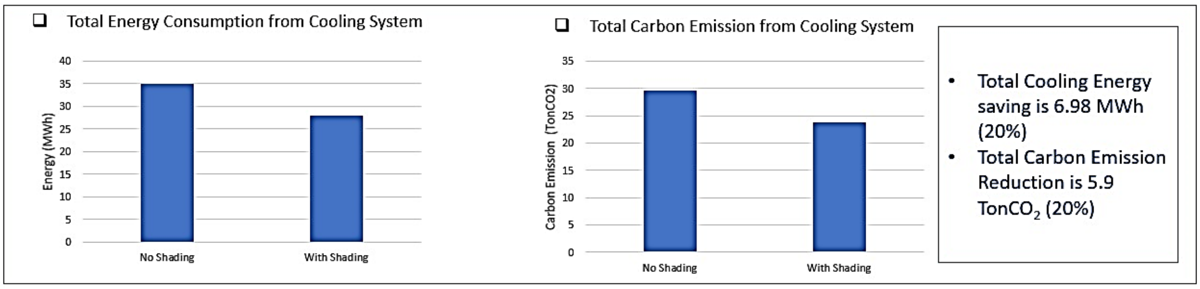

Fig. 20. Total CO2 Gas Emissions
Source: Hasil Analisis IESVE

In the SGLC co-working space, the total energy consumption is 34.98 MWh without the implementation of a double skin façade. However, with the use of a double skin façade, the total energy consumption is reduced to 28 MWh, resulting in a significant 20% reduction in energy consumption, which amounts to a savings of 6.98 MWh. In the SGLC co-working space, the absence of a double skin façade resulted in 29.9 tons of CO2 gas emissions. However, when utilizing a double skin façade, the overall energy consumption was lowered to 24 tons. This led to a notable decrease of 5.9 tonnes, equating to roughly 20%, in CO2 gas emissions.

CONCLUSION

Room Elevation

The double skin façade has no influence on the difference in heat obtained from the floor elevation. This is proven by the relatively similar heat gain values in each co-working space, even though they are at different floor heights (floors 4 - 10). There is a noticeable temperature disparity on the top level (11th floor) of the SGLC UGM edifice. The reason for this could be that the 11th floor is situated right next to the roof. Hence, unless a double skin façade is installed on this particular floor, it remains warmer than the other levels (floors 4-10) in the SGLC UGM building.

Room Location

According to our analysis, Co-working space 1 has a notable solar heat gain value of 6.9-9 MWh without a double skin facade. Yet, implementing a double skin facade can bring this value down to 5.3-6.6 MWh. The room has two substantial openings, one on the east and the other on the north side. Our evaluation indicates that the east-facing opening is the main contributor to the radiant heat gain (solar heat gain).

The second co-working space encounters notable solar heat gain, with a range of 7.3 to 8.7 MWh in the absence of a double skin facade. Nevertheless, implementing a double skin facade reduces this range to 5.3-6.55 MWh. The room's two openings, facing south and west, play a significant role in this heat gain, with the opening facing west being the primary contributor to the high temperatures.

When it comes to co-working space 3, it's worth considering that the total heat gain can range from 3.55 to 4.7 MWh without a double skin facade. However, by implementing a double skin facade, the range decreases to 2.7 to 3.2 MWh. It's worth noting that this space only has one opening facing the south, which results in the lowest total heat gain. This is due to the room's orientation, which protects it from direct solar radiation. The location of a co-working space greatly affects the amount of heat absorbed within its confines. This is largely due to the positioning of the openings in the space, with a high probability that those facing east and west contribute to the notable heat gain observed.

Double Skin Facade Effect

The impact of implementing a double skin façade on heat gain within co-working spaces can be summarized as follows: Without the use of a double skin façade, solar heat gain falls between 12.5-13.9 MWh. However, with a double skin façade, this range is reduced to 7.9-8.7 MWh. The lowest monthly solar heat gain achieved with a double skin façade reflected a decrease of 4.6 MWh or 35.66%, while the highest monthly solar heat gain showed a decrease of 5.2 MWh or 59.77%.

Based on our analysis of heat gain through conduction, co-working spaces without a double skin facade or with one demonstrate an average monthly heat gain of 6.1 - 7.7 MWh. It's worth noting that the double skin facade does not appear to have a significant impact on reducing heat gain through conduction in these spaces. Without implementing a double skin facade, the monthly average heat gain falls within the 19 to 21.9 MWh range. However, utilizing a double skin facade brings this range down to 14.1 to 16.1 MWh. This results in a reduction of 4.9 MWh or 25.79% for the lowest monthly average heat gain and a decrease of 5.8 MWh or approximately 26.48% for the highest monthly average heat gain.

Based on our analysis of the SGLC building within the Faculty of Engineering at UGM, we have found that the implementation of a double skin façade does not appear to significantly impact the building's heat gain through conduction. However, our research indicates that the use of a double skin façade can lead to a reduction of heat received by the building, with a range of 25.79-26.48% observed in the three co-working spaces on floors 4-11. Overall, it can be concluded that the passive cooling approach utilizing a double skin façade has been a successful effort in the SGLC building.

Average Monthly Heat Gain

Based on the data collected regarding the average monthly heat gain, it is evident that solar heat gain surpasses conduction heat gain when a double skin façade is not utilized. This is due to the significant amount of heat gain through radiation, particularly when the co-working space openings face east or west. In conclusion, the value of heat gain through radiation greatly outweighs that of heat gain through conduction.

In the event of implementing a double skin façade, the increase in heat from solar radiation surpasses that of conduction. Thus, it can be deduced that there is no noteworthy contrast in the conduction measurements obtained with and without utilizing a double skin façade. The total average value of monthly heat gain using a double skin façade is much lower than the situation without using a double skin façade. This shows that the use of double skin façade for passive cooling in SGLC buildings is quite effective.

Reducing CO2 Emissions Due to the Use of Double Skin Façade

Based on an analysis of building energy consumption data, it was observed that the use of double skin façade resulted in a decrease in energy consumption of 0.8 MWh or approximately 22.9% compared to the month of highest energy consumption (May). Similarly, in the month of lowest energy consumption (February), there was a reduction of 0.3 MWh or around 14.3%. These findings indicate that the reduction in energy consumption due to the implementation of double skin façade is more significant at higher energy values. Conversely, if energy consumption is already low without the use of double skin façade, the reduction in energy consumption from implementing it would be proportionally low as well.

According to the CO2 gas emission data, the use of double skin façade resulted in a decrease of 0.6 tons or approximately 20.7% when compared to the month with the highest CO2 gas emissions (May). Similarly, there was a decrease of 0.4 tons or about 21.1% in the month with the lowest CO2 gas emissions (February). These findings suggest that the reduction in CO2 gas emissions through the implementation of double skin façade is more pronounced in cases where CO2 emissions are high. Conversely, when CO2 emissions are low without double skin façade, the reduction achieved through its use will also be low.

The implementation of a double skin façade in the SGLC co-working space has led to an impressive 20% reduction in total energy consumption when compared to a scenario without one. This highlights the effectiveness of incorporating a double skin façade in reducing building energy consumption. The decrease in electrical energy usage for cooling loads in co-working areas was the primary contributor to the decrease in total energy consumption.

The implementation of a double skin façade in the SGLC co-working space has proven to be an effective method for reducing the building's CO2 gas emissions. In fact, the data shows a 20% decrease in total emissions when compared to a scenario without the double skin façade. The final conclusion from this research is that the use of a double skin façade in the SGLC building at the UGM Faculty of Engineering can help reduce CO2 gas emissions by 20% of the value without using a double skin façade.

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