Hybrid system strategy on double skin façade to optimize thermal performance on research building

Abdul Hakim Abdul Majid, Azhar Ghazali *

Architecture Programme, School of Housing, Building, and Planning, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia.

*Email: azhar.ghazali@usm.my

Abstract. One of the most efficient methods to optimize thermal performance in a building is the practical design of the façade. The double skin façade (DSF) is a crucial decision for handling the interaction between outdoor and indoor spaces. It also offers some spatial diversity in the design process. Recently, a lot of focus has been paid to it instead of the more traditionally glazed curtain wall. This is because of its potential to reduce energy effectively, achieve thermal comfort in the building, and save costs. The indoor spaces near to the glazed facades will become warm due to high incidence solar radiation on the East-West facades in Malaysia's tropical environment. In the tropics, one of the solar heat gain reduction approaches is the use of double skin-facade (DSF). One of the fundamental components of the double-skin façade is the blinds. Blinds located in the cavity of the double-skinned facade and buffer the building from solar heat gain or perform the role of a pre-heater for ventilation air. In general, the temperature of the blinds is high, which is helpful in the cold period but problematic in the hot period. To minimize the cooling loads of the building, technological innovations for the shading system are considered. Plants can dissipate absorbed solar radiation into resistant and latent heat. Plants turn radiation into the latent heat. This paper aims to study the effectiveness of a double skin façade and explore improved innovative design for a double-skin façade design integrated with vertical greenery on research building to optimize thermal performance. This paper will collect data of the thermal performance of double skin façade, precedent study and run simulation analysis to achieve the aim of the paper.

1. Introduction

1.1. Research Background
One of the most efficient ways to optimize thermal performance in a building is through building facade design. As one of the fundamental building elements, envelopes have a significant role to play in thermal performance [1]. The building envelope specifies the thermal balance between the outdoor climate and the indoor spaces and thus controls the total energy performance of the building [2].

The double skin façade is one of the best ways to manage the interaction between outdoor and indoor spaces because of its potential to reduce energy effectively, achieve thermal comfort in the building, and save costs [3]. Study shows that Double skin façade design is particularly adapted with the outdoor climate to apply cooling by natural ventilation and reduce energy consumption [4].

However, the air temperature in the cavity in the double-skin facade will be increased in the hot climate and the fully glazed of the facade will increase urban heat gain outside the building, especially with the hot and humid weather in Malaysia. The fully glazed double skin facade may not be the most suited for warm climates [5]. This paper aims to explore the innovative hybrid design strategies on double-skin façade integrate with vertical greenery design to optimize thermal performance on research building.
1.2. Purpose of Study
The purpose of this study is to explore an improved innovative design for a double-skin façade design on research building to optimize thermal performance. Furthermore, it is expected from the study, that to discover a hybrid strategy for a double-skin façade for research building in a tropical climate for a sustainable architectural environment. As a result, this can be used to guide the designer in designing a research building with the best double-skin façade approach in the tropical climate.

2. Literature Review: Thermal Performance of Double Skin Façade

- Double Skin Façade as Energy-Efficient Solution to Replace Window to Optimize Thermal Performance in Building
  Double Skin Façade (DSF) system that can be utilized as a balcony replacement when adapting to existing residential units. A Double skin façade was presented as an energy-efficient solution to replace existing windows in residences to optimize thermal performance in the building [6].

- Double Skin Façade with Natural Ventilated Cavity Achieve Thermal Performance
  The implementation of a double-skinned natural ventilated cavity in double skin façade design is a smart design practise, even in hot climates such as Malaysia, thereby offering a major opportunity to achieve thermal performance, low energy consumption and sustainable construction [7].

- Double Skin Façade Better Thermal Performance than a Single Skin Facade
  The findings show that the different DSF varieties have minimal variance in thermal performance, but that all DSF facades would have much better thermal performance than a single skin façade. The differences in the configuration of the DSF had a substantial effect on the energy efficiency of the forms investigated. However, thermal performance and energy saving vary depending on the type of atmosphere and the amount of DSF [8].

- Double Skin Façade Can Minimize Thermal Energy by Provide Good Cavity Ventilation
  In summer, double skin façade (DSF) can minimise thermal energy by providing good ventilation through its cavity (naturally or mechanically). Double skin façade can minimise thermal energy in summer by supplying good ventilation through its cavity (naturally or mechanically) and uses solar heat recovery to heat the building in winter, as well as good acoustic insulation in busy areas [9].

- Double Skin Façade Reduce Building Heat Losses and Gains
  Taking into consideration thermal impacts, the projected forecast has shown that double façades reduce all building heat losses and gains throughout the year and contribute significantly to building energy savings. The temperatures were recorded and are the basis for a basic measurement procedure proposed to assess the energy needs of the double skin facade [10].

3. Research Questions
The research questions for this study are as follows:
  i. How does double skin façade impact thermal performance in a building?
  ii. What is the thermal performance of double skin façade under tropical climate?
  iii. How does hybrid double skin façade improve thermal performance under tropical climate?

4. Research Objectives
The objectives of this study are to:
  i. To study thermal performance on double skin façade.
  ii. To investigate the thermal performance of double skin façade under tropical climate.
iii. To explore hybrid double-skin façade approach on thermal performance under tropical climate.

5. Methodology

5.1. Literature study on thermal performance of double skin façade

Literature study is used for this research. This method uses a direct and structured technique [11]. This method identifies research questions, further analyses the findings, reviews the reliability of the study, synthesises the results. Various academic papers and research on double skin façade and its thermal performance under tropical climate are reviewed. Terms like double skin façade, natural ventilation and thermal performance are used to search research papers on few websites. These websites are including Google Scholar, ScienceDirect, and ResearchGate. The findings are arranged in list of the thermal performances a double-skinned façade. The list of literature is then analysed as findings.

5.2. Precedent study on double skin façade in Malaysia climate: The securities commission (SCB) building

Study has been carried out by choosing a precedent study on building that use double skin façade in Malaysia climate. This research will be by findings from the internet, some of its own knowledge and feedback from experts and others. The building that was chosen for the case study is: The Securities Commission (SCB), Bukit Kiara, Kuala Lumpur, Malaysia.

![Figure 1. Floor plan and exterior perspective for The Securities Commission (SCB).[12]](image)

Building Description:
The Securities Commission (SCB) is a 1997-built mid-rise office skyscraper. It is in the Bukit Kiara neighborhood of Kuala Lumpur, Malaysia. In 2001, it received the ASEAN Energy Award (Hong, 2007). The structure has a gross floor area of 94,288 m² and consists of a six-story pedestal (with a three-story below-grade parking garage) and a five-story office tower (Figure 1). The SCB has double skin facades, which are made up of two layers of glass with a 1.2 m void between them. The exterior skin is made of low e tinted green glass (12 mm thick) while the inside skin is made of green glass (8 mm thick). A maintenance path and a cool buffer zone are provided by an air gap. Within the DSF cavity, shading devices such as horizontal louvers and vertical blinds are placed. Vertical blinds, regulated by solar cells, shield the workstation from direct sun radiation, particularly on the east and west sides. Cooled air from the office is recycled and vented into the DSF cavity at ceiling heights.

5.3. Simulation method

The final objective of the research is to analyze the proposed hybrid double-skin façade design approach integrate with vertical green to be compared to normal double-skin façade design. 3D
conceptual modelling of the hybrid DSF and current DSF will be modelled using SketchUp and then will upload on Ecotect software for analysis on thermal performance.

5.3.1. Conceptual modelling

Conceptual 3d modelling will be setup using SketchUp software. The parameter of the width of the cavity in double skin façade will be used based on the analysis from the precedent study of The Securities Commission Building (SCB). Two model including one with the proposed double skin façade that integrate with vertical green will take place (Figure 2).

The parameter for the 3d model has been taken from the precedent study of the SCB Building which is:

- Two layers of glass with a cavity = 1.2 m
- External glass skin thickness = 12 mm (thick low e tinted green glass)
- Internal glass skin thickness = 8 mm (thick green glass)
- Floor area size = 9.1m x 9.1m (Standard laboratory size 6m to 9.1m depth)
- Height = 4 meter

![Figure 2. Modelling using SketchUp shows two types of double skin facade along with the room space before transfer into simulation software for thermal performance simulation and analysis.](image)

5.3.2. Simulation analysis

The Ecotect program was used to do the quantitative analysis (Figure 3). ECOTECT is a complete environmental modeling software program designed for architects and engineers to use [13]. It enables for the effective depiction of environmental parameters such as diurnal temperatures, prevailing wind directions, available direct and diffuse solar energy, and sun path during the conceptual stages of design. Interior analysis tools are also included in the program, allowing for quick input on aspects including sun penetration, possible solar gains, thermal performance, internal light levels, reverberation times, and fabric prices. The conceptual model will be upload in the Ecotect software. Then analysis on thermal performance will be study (Figure 4). The data for Indoor Temperature will be taken for both 3d model and be compared and analyse.
6. Results and discussion

6.1. Precedent study: The Securities Commission (SCB) Building
The precedent study finds field research approach that conduct a thermal analysis of a double skin façade (DSF) exposed to direct solar radiation in a tropical building over the summer solstice's longest days, June 21st to 28th (Figure 5). As the result from the study, to be conclude in Malaysia's tropical climate, the contribution of outdoor air temperature to heat gain via Double Skin Facade is non-existent, according to the study. While direct solar radiation and, as a result, the temperature of the double-glazing surfaces has a significant impact on raising the indoor air temperature. In conclusion, the western façade requires direct shade, which is why the SCB included motorized blinds in the workspace. In a climate like Malaysia's, where the differences between outside and interior temperature are not as great and direct solar radiation is the major contributor to the indoor temperature, it is better to use advanced solar control glazing instead of a DSF with a huge cavity.
6.2. Simulation result and finding

For the thermal analysis, it will define as the temperature that will be created inside the interior space of the study model. The image that has been generated by the Ecotect created an understanding of the thermal analysis. The rendered images that produce by Ecotect were in color level. The image (Figure 6) will define the pattern of different color of the internal area of the model that will show the mapping of the interior part of study model. The analysis also been tested the same where it needs to define the effect that has been resulted when it was tested for eight days taken in summer, June 21st to 28th for a general space adjacent to the DSF that is exposed to west direct solar radiation. The difference of the result can be seen on the annual images where the illuminance creates a different exitance on that area and the graph generated by the Ecotect software that show indoor temperature for both double skin façade model.

The 3d model simulation for both model characteristics are set as below based on the precedent study of The Securities Commission Building (SCB):

- Two layers of glass with a cavity of 1.2 m
- The external skin is (12 mm) thick low e tinted green glass
- The internal one is (8 mm) thick green glass.

**Figure 5.** The relation between direct vertical solar radiations (west) and indoor air temperature. [12]
Figure 6. Indoor thermal analysis on hybrid double skin façade and normal double skin façade on 21st to 28th June.
6.3. Hybrid Double Skin Façade (HDSF): Vertical Green Integrated VS Normal Double Skin Façade (DSF) Approach

As the analysis of hybrid double skin façade and normal double skin façade model have done, the reading of the indoor temperature by the software will be taken and analyzed. The intention of these method is to differentiate the graph of thermal performance of the internal part of the model. The reading will be taking and arranged in table that will show the pattern of temperature difference between Hybrid Double Skin Façade (HDSF) and Double Skin Façade (DSF), while the whole data will be place in a table that represent by Eight days in June (21st to 28th).

| Date       | Temperature (°C) | Average Temperature Difference |
|------------|------------------|-------------------------------|
|            | Hottest          | DSF  | 26  | 23  | 20  | 24  | 24  | 19  | -   |
|            | Temperature      | HDSF | 20  | 21  | 18  | 20  | 19  | 16  | -   |
|            | Difference       |      | 6   | 2   | 2   | 2   | 4   | 5   | 3.25|
| Lowest     | DSF              | 12   | 14  | 12  | 8   | 14  | 10  | 11  | 12  | -   |
| Temperature| HDSF             | 11   | 14  | 12  | 9   | 14  | 10  | 11  | 12  | -   |
| Difference |                  | 1    | 0   | -1  | 0   | 0   | 0   | 0   | 0   |

Based on the Table 1, the results for Hybrid Double Skin Façade (HDSF) are slightly lower than the existing double skin façade especially during the hottest hour in a day which is at 2pm to 3pm. The lowest temperature during the day does not have much difference between both façade analysis because there is no presence of solar radiation which is at 4am to 7am. The difference in temperature during the sun hour because the building expose more on the solar radiation thus give impact on the temperature compared to night hour. The finding shows Hybrid Double Skin Façade (HDSF) that incorporated with vertical green in their cavity affect the temperature inside the building and the vertical green act as solar controller glazing.

7. Conclusions

In conclusion, the implementation of the hybrid double skin façade to the office and research space creates a new point of perspective on how efficient the double skin façade implementation to the full glazing façade of the building. The installation of the hybrid double skin façade that implement vertical green was satisfied as it will avoid the direct sunlight from entering a building, but it brings only indirect sunlight into the interior part of the building just with the right amount of sunlight. The amount of solar radiation that transmitted through the building space or study model was capable and follow the standard amount of thermal required in a space.

Based on the double skin façade that use in office or research building, a double skin façade type has been chosen in precedent study. Based on the façade that been chosen from the precedent study, the façade has analyzed with simulation with the proposed hybrid DSF to compare the thermal indoor performance. Therefore, different temperature was resulted in the findings as being tested in Ecotect software. The double skin façade was created in 3D SketchUp with two types of double skin façade to be tested.

This research also presents an integration of Ecotect simulation software as a digital tool to measure thermal performance parameters of double skin façade. The software was used to detect the level temperature that received in a study model space. As there are limitation in handling manual simulation, the most efficient way to find an optimal solution are by using digital tools. The results of digital tool showed success where the temperature can easily be detected by color that created in simulation images and by the analysis graph from the software.
The results obtained from the software are worthy of analysis. As a result, it provides results to show the difference between normal double skin façade (DSF) and proposed Hybrid Double Skin Façade (HDSF). The difference between the models shows different readings in temperature that determine each one has different integration with solar radiation. In the end, the results have concluded that a hybrid double skin facade that can control thermal performance because of the present of vertical green in its cavity. The vertical green act as the solar glazing that can improve the current double skin façade design.

Hybrid double skin facade may present solutions for a better energy-performing in architecture especially to a space that required thermal comfort. Therefore, the future intention of establishing a research space should take this into account implementation because it brings a great advantage to sustainable performance build in the future. The methods that are being used in this paper also may be tested and applied in the future which can be in relation with other criteria such as noise control, acoustic, ventilation, and visual exposure.

Acknowledgments

The authors would like to acknowledge Research University Grant Universiti Sains Malaysia (USM) (Grant No: 304/PPBGN/6315430) and School of Housing, Building, and Planning USM to enable this research to be conducted and giving the opportunity in obtaining the grant.

References

[1] Aslani, A., Bakhtiar, A., Akbarzadeh, M.A.(2019). Energy-efficiency technologies in the building envelope: Life cycle and adaptation assessment, Journal of Building Engineering, Volume 21, Pages 55-63,
[2] Sozer, H. (2010). Improving energy efficiency through the design of the building envelope. Building and Environment, 45(12), 2581–2593.
[3] Shameri, M.A., Alghoul, M.A., Sopian, K., Zain, M.F., Elayeb, O., (2011). Perspectives of double skin façade systems in buildings and energy saving, Renewable and Sustainable Energy Reviews, Volume 15, Issue 3
[4] Gracia, A.D., Castell, A., Navarro, L., Oró, Cabeza, L.F., (2013).Numerical modelling of ventilated facades: A review, Renewable and Sustainable Energy Reviews, Volume 22, Pages 539-549,
[5] Maryam, K., Zhonghua, G., Karine, D., Haşim, A., (2017). Thermal Environments of an Office Building with Double Skin Façade, Journal of Green Building
[6] Yoon, Y. B., Seo, B., Koh, B. B., & Cho, S. (2019). Performance analysis of a double-skin façade system installed in different floor levels of highrise apartment building. Journal of Building Engineering, 100900.
[7] Ayegbusi, O.G., Ahmad, A.S., Wah, L.Y., (2018). Overall Thermal Transfer Value of Naturally Ventilated Double Skin Façade in Malaysia, Journal Progress in Energy and Environment 5
[8] Aksamija, A., (2016) Energy Performance Of Different Types Of Double Skin Facades In Various Climates. Department of Architecture
[9] Faizi, F., Yazdizad, A., (2014). Classification of Double Skin Façade and Their Function to Reduce Energy Consumption and create sustainability in Buildings. 2nd International Congress on Structure, Architecture
[10] Andjelković, A. S. (2012). The Development of Simple Calculation Model, Thermal Science, Year 2012, Vol. 16, Suppl. 1, pp. S251-S267.
[11] Armstrong, R., Hall, B. J., Doyle, J., & Waters, E. (2011). ‘Scoping the scope’of a cochrane review. Journal of Public Health, 33(1), 147-150.
[12] Qahtan, A.M.,(2019).Thermal performance of a double-skin façade exposed to direct solar radiation in the tropical climate of Malaysia: A case study, Case Studies in Thermal
Engineering, Volume 14.

[13] Marsh, A.J., (1996) Integrating Performance Modelling into the Initial Stages of Design, in ANZAScA Conference Proceedings, Chinese University of Hong Kong.