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DOUBLE SKIN FAÇADE: A GREEN BUILDING STRATEGY APPROACH TOWARDS LOW CARBON ARCHITECTURE

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ABSTRAK

The emergence of global warming due to the increase in the amount of carbon emissions and greenhouse gas emissions is caused by one of the activities of the construction industry sector. Green building is one of the solutions that can help reduce energy consumption in buildings and carbon emissions in the building life cycle. Double Skin Façade (DSF) is one of the green building strategies that can be applied to new and existing buildings. This study aims to determine the type of DSF used in the field and how DSF can affect the energy consumption of buildings. This research uses a narrative review method that focuses on the application of the DSF strategy, how the mechanism works on the type of DSF used. The results show that the use of DSF is able to reduce HVAC energy loads in buildings in various types of climates. Stack effect as a key capability of DSF is able to create airflow in the air gap so as to stimulate air movement which in turn can reduce the use of HVAC in buildings. This shows that the DSF strategy is one of the green building strategies that has great potential to be developed in the future

KEYWORDS: green building strategy, energy, carbon emission, double skin facade

Munculnya pemanasan global akibat dari kenaikan jumlah emisi karbon dan emisi gas rumah kaca disebabkan salah satunya kegiatan sektor industri konstruksi. Bangunan hijau merupakan salah satu solusi yang dapat membantu mengurangi konsumsi energi pada bangunan dan emisi karbon pada siklus hidup bangunan. Double Skin Façade (DSF) merupakan salah satu strategi bangunan hijau yang dapat diterapkan pada bangunan baru maupun bangunan lama. Tujuan dari penelitian ini adalah mengetahui tipe DSF yang digunakan di lapangan dan bagaimana DSF mampu memberikan pengaruh terhadap konsumsi energi pada bangunan. Penelitian ini menggunakan metode narrative review yang berfokus pada aplikasi strategi DSF, bagaimana mekanisme kerja pada tipe DSF yang digunakan. Hasil penelitian menunjukkan bahwa penggunaan DSF mampu menurunkan beban energi HVAC pada bangunan di berbagai jenis iklim. Stack effect sebagai kemampuan kunci DSF mampu menciptakan aliran udara pada air gap sehingga mampu menstimulasi adanya pergerakan udara yang pada akhirnya mampu mengurangi penggunaan HVAC pada bangunan. Hal ini menunjukkan bahwa strategi DSF merupakan salah satu strategi bangunan hijau yang memiliki potensi besar untuk dikembangkan di masa depan.

KATA KUNCI: *strategi bangunan hijau, energi, emisi karbon,* double skin facade

INTRODUCTION

The high level of energy consumption in buildings and other resource factors such as land which reaches 18% has a very large role in the amount of CO2 emissions globally (Chatwani et al., 2018) , The increase in greenhouse gas emissions and CO2 emissions in general by 40% mostly comes from the construction and building industry sector (Liao & Li, 2022; Liu & Leng, 2022; Rattedatu et al., 2023; Tao et al., 2021). Thus, some activities in the construction and building industry sector that can reduce the amount of CO2 emissions will have a significant impact on overall global warming. This is very important to know because global warming will cause environmental damage and climate change.

Several strategies can be applied to reduce the amount of CO2 emissions generated from the construction and building industry sectors. One strategy that can be applied to reduce CO2 emissions is the concept of green building. Green building strategy approaches that can be responsible for CO2 emissions include building facade systems that are directly related to the embodied energy and operational energy of buildings (Zhou & Herr, 2023) . An adaptive façade system is an alternative solution that emerges in accordance with the need to overcome building technology problems that can adapt to microclimate conditions. Double skin façade (DSF) is one of the adaptive building façade technologies that has a multiple layer configuration (GhaffarianHoseini et al., 2016). The trend of using DSF is increasing because it can be applied to new buildings and old buildings (retrofitting) (Lops et al., 2023).

This research aims to provide a holistic view of DSF technology strategies, especially typical DSF glass in achieving energy efficiency in buildings. The approach is carried out through typology analysis, basic concepts of typical DSF through best practice examples in the use of DSF.

DSF Design Typology

DSF principally consists of three layers, the outer layer (the part connected to the external environment of the building), the air gap (the air space separating the outer and inner layers), and the inner layer (the layer connected to the interior of the building). Initially, DSF generally utilized glass material in both the outer and inner layers of the building (Preet et al., 2022; Unluturk & Kazanasmaz, 2024) . However, in its development DSF began to utilize other materials to be used in the outer layers, such as plants, Photovoltaic panels, thermal mass (Ioannidis et al., 2020).

The air gap in DSF has a size of 200 to 1000mm and in some cases there is shading in the air gap area which functions to remove heat flow (Preet et al., 2022). The use of internal shading in the air gap layer depends on the type of DSF construction used.

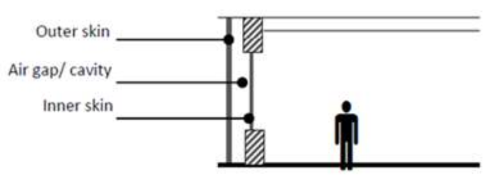

Figure 1. Komponen DSF
(Source: Dewi, et.al, 2013)

Double Skin Facade Type

DSF has several types that are distinguished based on the construction and ventilation mechanism used (Dewi, 2013).

a. Based on facade construction

In a Multi-Storey DSF, each floor of the building can have its own double skin facade unit, creating a vertical stack of double skin elements. This design allows for better control of natural ventilation, solar gain, and thermal insulation on each floor of the building. The multi-storey DSF configuration offers several advantages, viz: improved energy efficiency. By providing insulation and reducing heat loss, Multistory DSF can help lower energy consumption for heating and cooling. Another advantage is increased indoor comfort. The air corridors between the glass layers can serve as buffer zones, helping to maintain a more stable indoor temperature and reduce drafts.

There are 4 types of DSF division based on façade construction, namely: box window façade, shaft box façade, corridor façade and multistory façade. It can be seen from the type of construction that each type has a different air gap compartment design (Lops et al., 2023; Naddaf & Baper, 2023; Preet et al., 2022).

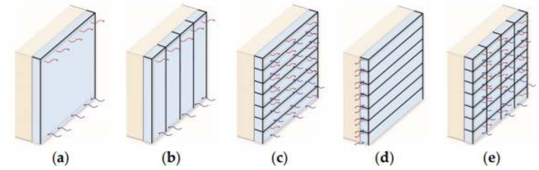

Figure 2. Tipe-tipe DSF berdasarkan konstruksi (a. multistorey, b. shaft box, c&d. corridor, e. box-window)
(Source: Lops, et.al, 2023)

b. Based on ventilation mechanism

The division of DSF based on its ventilation system is divided into 3 types, including: natural ventilation, mechanical ventilation and hybrid mechanism. The use of natural ventilation in DSF utilizes thermal behavior, stack effect. While the hybrid ventilation system utilizes both types of systems, but the use of mechanical equipment assistance is used only when the natural ventilation system is not sufficient to maximize its performance (Tao et al., 2021).

Double Skin Facade Material

Glass is a vital material in DSF because it is used in both layers of DSF components (inner and outer skin). Glass acts as a barrier between the building's inner space and the outside environment. By using glass with good thermal insulation properties such as Low-E Glass, DSF can help reduce heat transfer between the inside and outside of the building, thereby reducing energy requirements for heating and cooling. By using glass with good heat rejection properties, DSF can help reduce excessive heating inside the building due to solar radiation. This can improve the thermal comfort of building occupants and reduce cooling loads.

There are several types of glass that are commonly used in building facades. Each type of glass has different optical properties and affects the acceptance of heat radiation and lighting inside the building. The different types of glass used are influenced by the optical properties of the material, including the values of visible and solar transmittance, conductivity, u-value, and SHGC (Catto Lucchino et al., 2022). Transmittance is the ability of the glass to transmit daylight into the building affecting the level of natural lighting in the room. Glass with high transmittance can maximize daylighting, reduce the need for artificial lighting, and create a comfortable environment for occupants.

Reflectance is the ability of glass to reflect sunlight affecting the amount of heat absorbed by the building. Glass with high reflectance can reflect some of the sun's radiation, reduce excessive heating in the building, and reduce cooling loads. While absorptance is the ability of glass to absorb energy from solar radiation affecting the level of heating in the building. Glass with high absorptance will absorb more heat energy, which can increase indoor temperatures and require additional cooling. Another important optical properties point is the U-Value. The U-Value of glass measures the level of thermal insulation of the glass, which is the ability of the glass to inhibit heat transfer. Glass with a low U-Value will help keep the temperature in the building stable, reduce thermal energy leakage, and improve energy efficiency.

METHODS

The method used in this research is descriptive literature review. The literature review was conducted with the approach of exploring the basic definition of DSF, design typology, mechanism, construction type of DSF and types of buildings that allow DSF to be applied. The selection of case examples of the use of DSF as best practice was carried out to be analyzed based on the aspects of DSF that have been reviewed to gain an understanding of the advantages of using DSF strategies and their influence on building energy efficiency.

The research began with a literature review by collecting journal data on the topic of DSF. The next step was to sort the journals based on the typology of the DSF skin or skin. Some researchers define DSF with inner and outer skin glass. Whereas in its development, some other researchers define the outer skin of DSF as the outer skin of the building which can use materials other than glass. This research focuses on DSFs with inner and outer skin types that use glass material. The next step is to deepen the study of several factors in glass DSF types such as mechanism, construction system and building type. Best practice is the end of this research to look holistically at the factors in DSF that can affect the energy performance of buildings.

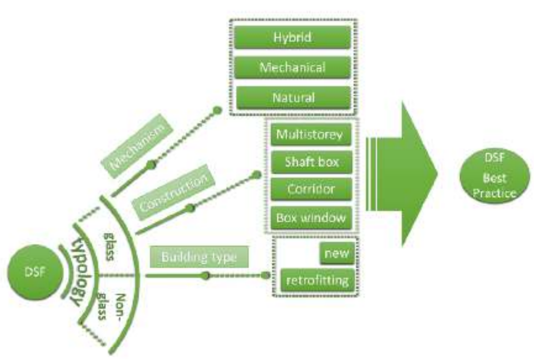

Figure 3. Theoretical framework
(Source: Author's analysis, 2024)

RESULTS AND DISCUSSIONS

Technology applications in buildings to support the achievement of buildings in reducing the level of energy consumption in buildings can be divided into the utilization of renewable technologies and advanced facade technologies (Lai et al., 2023) . Some previous research states that the use of green building strategies that have the most influence on achieving green building performance is in the application of technology to the building facade through the integration of passive and active strategies in buildings (Zhou & Herr, 2023). The double skin façade (DSF) is one of the most feasible technologies to be further developed in the future by utilizing PCM integration (Zhou & Herr, 2023). DSF components by utilizing air gaps.

1. Multistorey DSF Office in Korea

One example of the application of the DSF strategy is a multistorey DSF in Korea (Joe et al., 2014) . The type of glass used in the outer layer is 6mm single glazed and the inner layer uses double glazed LowE with an air gap width of 78cm. The optimization study was carried out under initial conditions with a fairly low energy consumption level value of 20 kWh compared to the optimization model carried out based on the modification of glass type and air gap width. The optimization methods used to analyze the energy consumption of closely conditioned zones in the research on the optimal design of multi-storey double skin facades include GenOpt and Particle Swarm Optimization (PSO). GenOpt is a generic optimization program used in this study to optimize the design parameters of double skin facades. PSO is a population-based stochastic optimization technique inspired by the social behavior of flocks of birds or schools of fish, which is likely to be used to optimize building energy consumption. This optimization method is applied to find the most energy-efficient design for double skin facades, considering variables such as window glass type and cavity depth.

The working mechanism of Double Skin Facade (DSF) involves the use of two layers of glass separated by an air space or vacuum between them. The air space between the two layers of glass acts as an additional insulating layer that helps reduce heat transfer between the outside and inside of the building. This helps to keep the temperature inside the building stable, reducing the need for heating and cooling.

DSFs can be designed with natural ventilation that utilizes the air space between the glass layers for air circulation. Hot air trapped between the outer and inner glass can be exhausted through the top or side vents, while fresh air from outside can enter through the bottom vents. This natural ventilation helps improve the air quality in the building. DSFs can be designed with glazing that has certain heat rejection or solar radiation absorption properties. This helps to reduce excessive heating inside the building due to direct solar radiation, thereby reducing the cooling load.

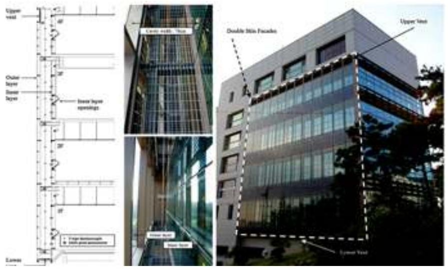

Figure 4. Best practice on parametric study of multistorey DSF in Korea
(Source: Joe, et.al., 2014)

2. DSF in residential houses in Japan

The use of DSF is not only possible in public buildings with a large number of floors, but also possible in residential buildings. An example of the application of DSF strategies with hybrid ventilation mechanisms is in residential buildings in Japan (Xu & Ojima, 2007). The material used in the outer and inner skin layers uses a type of clear glass with a thickness of 8mm and 6mm for the outer and inner sides respectively. Utilization of stack effect in summer can reduce 6-10% of solar heat entering the building so as to reduce cooling energy. DSF was used in a two-story residential house in Kitakyushu, Japan. The DSF works on the following principles: stack effect, During summer, the hot air inside the DSF room rises upwards due to the temperature difference with the outside air. This hot air is then expelled through natural ventilation, helping to cool the building. The stack effect during summer encourages the upward movement of hot air due to the temperature difference between the interior and exterior. This natural airflow allows hot air to be expelled through ventilation openings, reducing the need for mechanical cooling systems. In winter, DSFs capture solar radiation through a double layer, creating a greenhouse effect that helps retain heat indoors, reducing heating loads. DSF enables effective temperature adjustment with different operating modes during transitional seasons, such as fall. This helps in optimizing thermal comfort and reducing energy consumption.

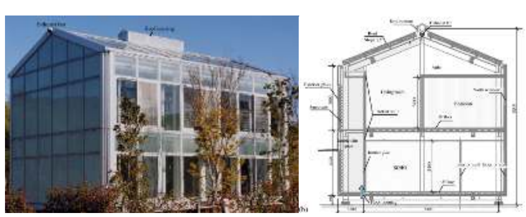

Figure 5. Best practice residential house with DSF in Japan
(Source: Xu & Ojima, 2007)

3. DSF on Palerno Building in Italy

The Palerno building in Italy is one example of a building that has implemented the DSF strategy (Flores Larsen et al., 2015) . The DSF strategy is applied to the western facade of the building. There are two types of DSF construction installed in this building, namely the corridor type at the bottom and the multistorey type on the upper floors. The air gap in the corridor type is 2m, while in the multistorey type it is 1.7m. The evaluation results of the DSF use show that the indoor temperature with DSF corridor type is around 25°C, which means it is not different from the room temperature in general. DSF can reduce direct solar radiation entering the building. With an additional layer of glass on the facade, some of the solar radiation is absorbed, reducing the heat entering the building's interior. DSFs do this by modifying the building's surrounding environment, such as air temperature, solar radiation, and wind speed, helping to reduce the air temperature inside the space and reducing the cooling load required. DSFs that use high-quality glass and good insulation layers can reduce heat transfer from warm air inside the space. This helps keep the indoor temperature stable without using too much cooling. Effective ventilation in DSFs can also help reduce the indoor air temperature and reduce the need for cooling.

Figure 6. Best practice use of DSF in an office building in Italy
(Source: Flores Larsen et al., 2015)

4. DSF at Cambridge Public Library

The Cambridge public library building has a transparent glass facade. The southwest wall utilizes a DSF system that uses a steel structure tied to the main structure of the building. The width of the air gap in this DSF is about 3-ft. The outer skin of the building is translucent glass that has solar shading that functions as light selves in the form of aluminum grids that fill between the air gaps. The inner skin of the building uses insulating glass. The use of transparent material on the building wall is a symbol of openness and welcoming nature and has an attachment to the park next to the building. In addition, the nature of transparency allows communication between the outer and inner spaces of the building (Alhazzaa, 2021; Vaglio et al., 2010).

The effect of using DSF with a mechanical system at the top of the air gap allows air movement into the air gap. In winter, the inlet and outlet of the air gap are closed, creating a thermal space that can warm the space inside the building (GhaffarianHoseini et al., 2016) . While in summer, outside air is drawn into the air gap by the principle of stack effect. In other seasons such as fall and spring, the air space inside the air gap can be utilized by operating the open-close wall so that the air can move inside the air gap effectively.

In addition to the building skin material, the presence of shading in the form of porous aluminum venetian blinds on each floor serves to reduce glare from sunlight entering the room, and increase effective natural lighting into the library space. The centralized control system uses a building management system so that it can run effectively. The shading louvers are closed in winter to reduce glare, while in summer the shading is able to help irradiation by adjusting the angle of the louvers so that the optimal angle of sunlight entering the building is obtained

Figure 7. Best practice use of DSF in a library building in Germany (Source: Alhazzaa, 2021)

5. DSF in an office building.

City Gate Düsseldorf, Germany, was built in 1997 and is a high-rise building with an office function with a height of 16 floors (Wong, 2008) . This building applies DSF with an air gap width of 1.4m. The type of DSF in this building is corridor façade. This building has utilized the BMS (building management system) feature to control the air conditioning system in the building. The air gap is equipped with a shading feature that is placed at a distance of 200mm from the outer skin of the DSF and functions to work automatically on the level of light illumination captured. The DSF in this building uses a mechanical type of ventilation that is useful in reducing the cooling load on the building by pushing hot air in the air gap up and out through the vents at the top of the DSF. The outer skin of the DSF uses toughened planar glazing of low-iron 'opti-white' glass with a thickness of 15mm which serves to achieve maximum glass transparency value as a lighting function into the building. While the inner skin uses double glazed Low-E glass. The use of the right DSF system can reduce the temperature of the air entering the inside to 2 degrees lower than the outside air temperature. Energy savings are assessed by the heating load on the building in the range of 30kWh/m2 thus showing this building as one of the energy efficient buildings.

Figure 8. Best practice use of DSF in an office building in Germany (Source: Wong, 2008)

Tabel 1. Best practice DSF

Building Function	Researcher	Year	Location	DSF Orientation	DSF Construction	Outer skin	Air gap	Inner skin	DSF ventilation system	Energy efficiency
Office building	Joe, et.al.	2014	Korea	South	Multistorey	Low E glazed 8mm	0.78m	Single glazed 8mm	Mechanical	Optimization reduced energy by 20kWh
Residential	Xu & Ojima,	2007	Japan	South	Corridor	Clear glass 8mm	1.23 mm	Clear glass 6mm	Natural ventilation	20-30% reduction in heating load in winter; 6-10% decrease in cooling load
Office building	Flores Larsen et al.	2015	Italy	West	Corridor (1st floor) Multistorey (2-5th floor)	Low E glass 6mm	2m	Clear glass 6mm	Natural ventilation	Maintain the temperature inside the building at 25°C, making it more energy efficient

Library	Vaglio et al., Ghaffarian Hoseini, et al., Alhazza, Kifa	2010 2016 2021	US	Southwest	Corridor	Translucent glass	0.9m	Insulated glass	Mechanical	Reduce the heating load on the building as well as the total energy consumption by -5.6%
Office	Wong, P	2008	Germany	The three sides	Corridor	toughened planar glazing of low-iron 'opti-white'	1.4m	double glazed Low-E	Mechanical	Minimize the temperature difference between outside and inside the building by up to 2 degrees Heating energy 30kWh/m2

CONCLUSION

Double skin façade as one of the green building strategies by utilizing the thermal concept in the building through the configuration of layers and materials on the facade of the building. the airing mechanism in DSF is determined based on local microclimatic conditions. hybrid mechanisms are used when natural systems cannot trigger air movement in the DSF space. Through examples of DSF applications, we can see the various types and mechanisms of DSF used in the field. All DSF systems in various climates have proven to be effective in saving HVAC energy use in buildings. The use of low-E glass in the outer skin layer of DSF provides an advantage in reducing the cooling load or heat load in the building. DSF is proven to be effective in reducing energy consumption for cooling and heating the house. During summer, the stack effect in the DSF space helps reduce the cooling load by utilizing natural ventilation. Meanwhile, the greenhouse effect in winter helps retain heat indoors, reducing the heating load by 20-30%. The DSF system facilitates natural ventilation, which helps in cooling the building by removing heat naturally and reducing reliance on mechanical cooling.

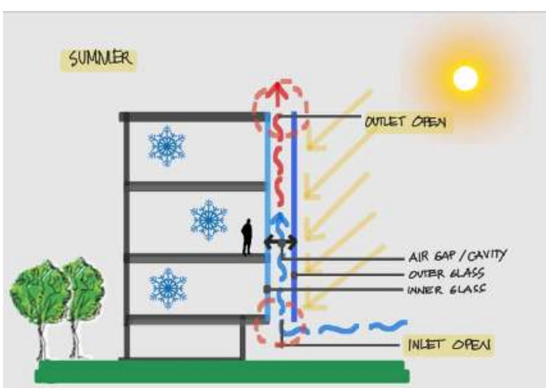

Figure 9. Schematic concept of DSF mechanism in summer (Source: Author's Document, 2024)

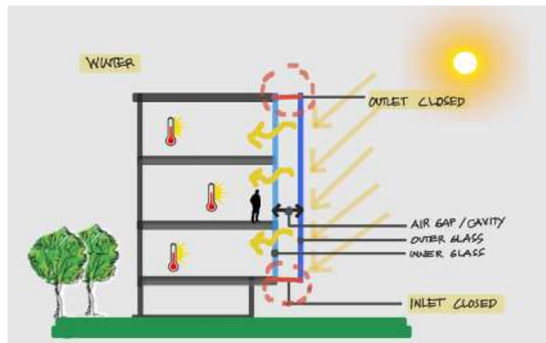

Figure 10. Schematic concept of DSF mechanism in summer (Source: Author's Document, 2024)

The corridor type of DSF is most widely used in buildings. Buildings in Europe and the US mostly place DSF on the west-southwest side, while in Asia, DSF is placed on the south wall of the building. The key role lies in the DSF's ability to "lure" airflow into the air gap or air gap between the inner skin glass and outer skin glass during the summer, which is called the stack effect. This cold airflow is utilized to enter the room, thereby reducing the use of space conditioning. Conversely, in winter, the DSF inlet and outlet are closed to trap hot air in the room so as to make the temperature in the room warm and reduce the use of heating in the room. The performance of the DSF can help minimize the use of HVAC energy in buildings. Future research can further compare the use of DSF in regions south of the equator to see how this strategy is implemented and the performance of DSF achieved.

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