APPLICATION OF DOUBLE-SKIN FACADE (DSF) IN TROPICAL CLIMATE COUNTRIES: A CASE STUDY OF SUASANA PJH TOWER IN PUTRAJAYA

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ABSTRACT

Double skin facade (DSF) is often heard and easily found in cold climate countries. For those countries, DSF are often used for heating mechanism to avoid heat loss. The solar-heated air contained in the cavity can heat the space outside the glass, reducing the need for an internal heating system. Due to the scorching sun that causes hot temperatures every day, DSF is rarely detected and be applied in tropical climate countries. However, DSF can still be used in the tropical climates with some modification to its parameters. The aim for this paper is to investigate the application of double skin facade in the tropical climate countries. Literature review on several resources such as journal, proceedings, book, and web surfing are conducted. Suasana PJH tower, Putrajaya that applied DSF in the building was selected as a case study. From the research, it can be concluded that DSF can be beneficial, but at the same time, can be a problem depending on the application of the DSF. The result for this research will be a reference and a guidance for researcher to design a building with proper application of the DSF.

Keywords: *Double-skin Facade, DSF, Tropical Climate, Case Study, Malaysia*

INTRODUCTION

A double skin facade (DSF) is an envelope consisting of two transparent "skins" interconnected by an air corridor (Khairdzir and Taib, 2020). DSFs are found primarily in cold climate countries, where the idea of the hot air circulates in the cavity between double skin acts as a barrier to heat loss, thus reducing the dependence on heating systems in the buildings. Regardless, DSF can also be beneficial in tropical climate countries. DSF could be integrated with passive design strategies such as daylighting, solar energy, and natural ventilation to help improve the comfort of the occupants of the building. This double-skin façade provides the right barrier between the internal and external environment.

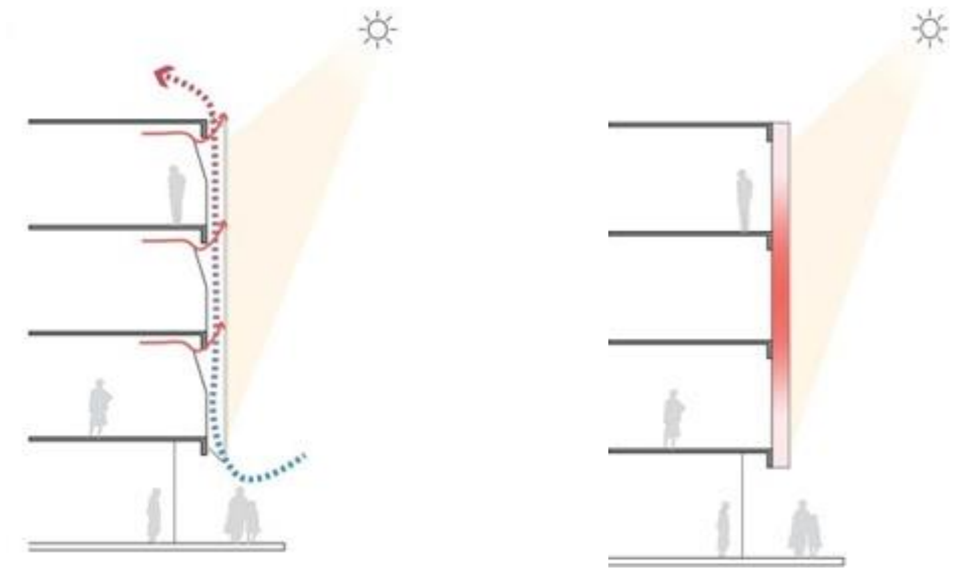
Tropical weather has an average monthly temperature of 18°C or higher and a hot climate all year. There will be normally two seasons: the rainy season (monsoon season) and the dry season. One of the three fundamental tropical climatic categories is the rainforest climate, which may be found in Latin America, West Africa and Central Africa, the West Indian Islands, Southeast Asia, New Guinea, and Australia. Located near the equator, Malaysia has a tropical rainforest climate, which is hot and humid throughout the year with an annual temperature of 25.4°C (World Bank Climate Change Knowledge Portal, 2020). May and June are the warmest months of the year, with approximately six hours of direct sunlight every day with cloudiness is frequently detected during afternoon and evening. The aim for the research is to investigate the application of the Double Skin Façade (DSF) in the tropical climate countries including its strategy and mechanism that need to be considered.

METHODOLOGY

This methodology adopted for this paper is literature reviews where the approach of qualitative research was conducted on a case study, which is Suasana PJH building in Putrajaya, Malaysia. The literature reviews were carried out through several resources such as journal, book, and web surfing to understand the mechanism of the DSF, the typology, the connection with building form and its application in hot climate countries and cold climate countries.

DSF APPLICATION IN HOT CLIMATE COUNTRIES AND COLD CLIMATE COUNTRIES

DSF consists of variety of characteristics depending on the desired modification of the facade andtemperature of the certain climate. DSF modification can vary from the type of weather, the form, and the façade construction. Constructing DSF should consider the airflow at the cavity which largely influences the indoor and cavity temperature.



(a) (b)

Figure 1. Comparison of heat mechanism in the DSF. (a) DSF in hot climate countries. (b) DSF in cold climate countries (Souza, 2022).

Figure 1 shows the application of the DSF in hot climate countries in comparison to cold-climate countries. In a situation where the building is located in the hot climate region, DSF act as shading device from direct sunlight, which allow temperature to drop at the inside of the building. The cavity between the building and the façade provides a space that channeling out the heat. The excess heat is removed by a process called the chimney effect. When the temperature inside the cavity is rising, the heat is pushed outwards, bringing cool breeze to the space and eventually to the inside of the building. On the other hand, in the cold climate countries, the temperature is chilly for most of the year. Some of the cold climate countries are Antarctica, Canada, Russia, and Mongolia, where the buildings are equipped with excellent heating systems. Based on the Figure 1 above, DSF in the cold climate countries act as an air buffer as well as a barrier to prevent heat loss. The solar-heated air helps warm the space outside the glass, eliminating the requirement for an internal heating system.

DSF AND BUILDING FORM

According to Figure 2 below, in term of form, DSF can be designed as box window, corridor, or multi-story type (Oesterle et al., 2001). Facades that are constructed with vertical and horizontal partitions are considered as window or box. When the facades were partitioned horizontally, it will be considered as a corridor facade. Multi-story facade does not have partitions neither horizontal nor vertical, instead, it was equipped with an air cavity in between with a large opening near the base and the roof of the buildings.

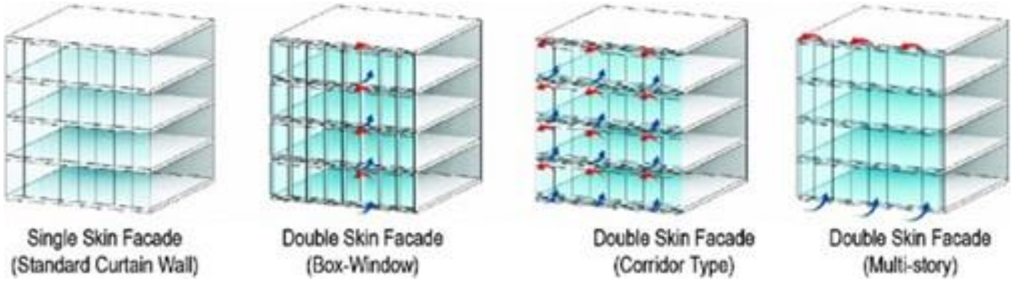
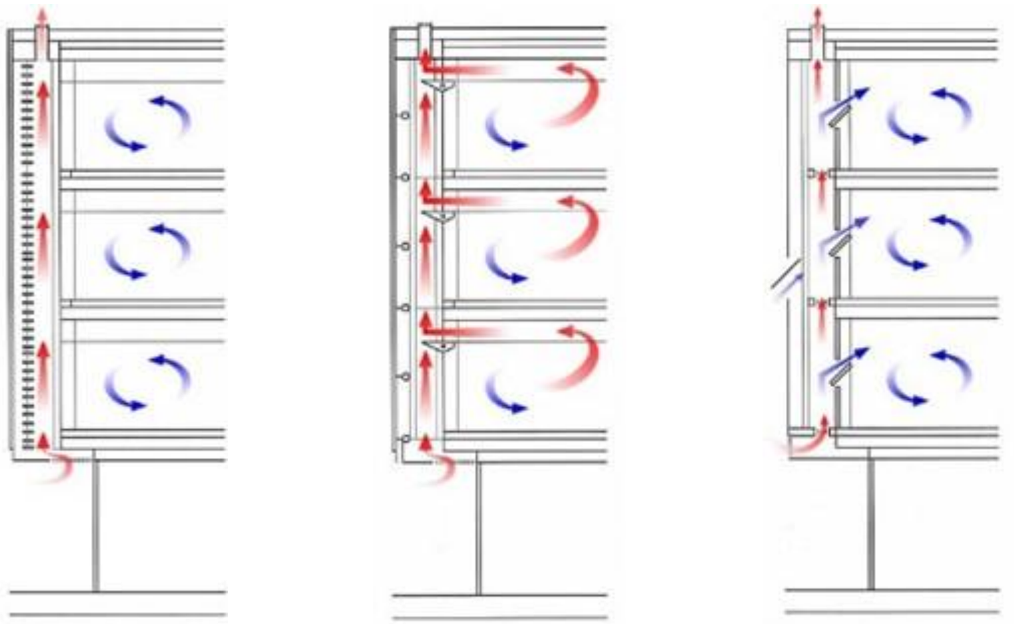


Figure 2. Relationship between DSF and building form (Aksamija, 2017).

TYPE OF DSF

According to Pollard and Beatty, 2008), there are 3 types of DSF in terms of construction which are buffer facade, extract-air facade, and twin-face facade. Every type of facade has its own benefits and performances which fit the purpose and climates of particular building.



(a) (b) (c)

Figure 3. Type of DSF. (a) Buffer façade system (b) Extract-Air Façade System (c) Twin Face System (Boake, 2003).

According to the Figure 3 above, the buffer façade system is applied to preserve natural lighting in the building and at the same time, enhance insulation and acoustics aspects. Mechanical means such as HVAC system or casement windows which cut through the double skin can be fitted to allow fresh air into the buildings. The hollow layers are set between 250 and 900 mm apart and can be covered by a shading device (Boake, 2003). This extract-air façade system is typically equipped with ranges from around 150mm to 900mm spaces for access to the cavity for cleaning purpose. The space between two layers becomes part of HVAC system where the used air from the inside of the building is extracted out while the outer layer minimizes heat transmission loss. The system is where natural ventilation is not possible (Boake, 2003). On the other hand, twin face system provides a cavity of 500 to 600 mm to accommodate cleaning service. The outer layer act as a shading device that protects the interior space from extreme weather and natural daylighting. With the system, the internal skin offers insulating properties to minimize heat loss. The system also allows natural ventilation to take place through operable openings in the internal and external skins (Mohamed and Alibaba, 2015) (Boake, 2003).

DSF can be beneficial to a building as well as a problem depending on the application of DSF. One of the benefits is the system able to reduce cooling and heating demand. The temperature of the interior surface of glazing systems must be considered since it is a source of heat energy. User comfort is also associated with the capability of the system to manage the light penetration through louvers or shades and the ability to manage air flow with operable windows (Eslamirad and Sanei, 2016). The air in the space between the two facade layers efficiently monitors itself in warmer regions. During the colder months, the gap between the two layers might serve as insulation, eliminating the demand for HVAC system, associated with running cost (Cassandra, 2018). Besides, DSF also acts as a protection or shading devices from extreme weather such as rain, wind, and degradation.

Maintenance issues with protected shading devices are often seen as a technical issue for DSF. The diameter of the air gap ranges from 200 mm to several meters or more. The space can provide high ventilation rate. However, small working space results in difficulty in cleaning purpose. This is a downside, particularly on plots where buildability is maximized. Double skin facades will be costly to build and require more to maintain and operate. DSF system consists of two layers, thus it requires twice as much cleaning, inspection, servicing, maintaining, and running. This may increase the expenses of a service and may negatively impact the occupants because they may have to cope with the sounds of cleaners or other maintenance on occasion (Miquel, 2020).

CASE STUDY AND ANALYSIS

Suasana PJH Building is located in Putrajaya and acts as a public community vitality to the often-monotonous Putrajaya Boulevard. The building was designed by T.R. Hamzah & Yeang Sdn. Bhd. and is a mixed-use complex with a landscaped central boulevard and planting spaces that integrate with urban fabric and public realm. The remarkable double-skin energy-saving facade with a fritted-glass outer-skin is based on the metaphor of a faceted diamond, molded as a crystalline structure, with the 'gem' becoming Putrajaya's defining centerpiece.

Figure 4. Suasana PJH Building in Putrajaya (Otosection, 2022).

Based on the case study, DSF can be used to produce thermal comfort in either tropical or cold environments. The depth of the cavity, shading devices, the material of the outer skin, glazing quality, structure, and cavity openings are factors that influence DSF design characteristics. Suasana PJH Building consists of Buffer Façade System in the DSF type of construction and shaft-box for the DSF and building form.

(a) (b)

Figure 5. Pattern design that can be seen on the DSF at the Suasana PJH Building, Putrajaya. (a) View from the outside (b) Close up view (Otodesign, 2022).

The facade is made up of two skins: transparent glass on the inside and 50% opaque glass fritted with a ceramic pattern on the outside. The exterior shading glass is constructed with glazed heat reinforced glass with high thermal load resistance. Based on the Figure 5 above, the outer glass façade was designed and lined with a ceramic Malay "Songket" pattern, provides the shade needed for the building. The DSF façade occupies 50% of the surface and most of the sun penetrating to the inside through the windows is blocked, and a tilted facade is used to block the sun from the East and West.

Besides, textile ceramic pattern is one of materials that can be used as outer skin. It is considered as a lightweight structure which reduces the weight and size of the primary structure and highly contributes to solar protection and glare control. It is a cheaper solution than normal DSF with the same function as other DSF material which bring natural lighting and has acoustic properties to urban environment. This material is applied in Suasana PJH Tower which reduces the complexity in structure design and cost-effective.

The depth of the cavity has a direct impact upon whether DSF may perform its functionality. According to the case study, Suasana PJH tower, the building has fewer cavity gaps, which will result in a higher ventilation rate. This produces a chimney stack ventilation effect, which naturally evacuates hot air from the lower level. The air between the two walls is heated by solar radiation from the outside and warm used air from the inside through the gap between the floors, continually moving, limiting heat migration to the interior rooms, and falling air pressure. Thus, this situation creates a lower pressure and reduce thermal heat on the inside of the building.

The exterior material influences the degree of absorption of heat to the façade, which may affect heat flow to the internal skin and inner spaces. Even though the shading devices able to reduce heat transfer from the outside and benefit the occupant's indoor thermal comfort, the degree of heat transmission is also determined by the glazing quality. Reflective glass, for example, will reflect heat well but may lead to blindness to pedestrians and drivers due to glare. The DSF of the Suasana PJH Tower was constructed with long vertical fins, equipped with fritted ceramic glass with glazing properties for its exterior façade, whichresult in less reflection. The small area exposed to direct sunlight is insignificant for direct-hit gain to occur at the inside of the building.

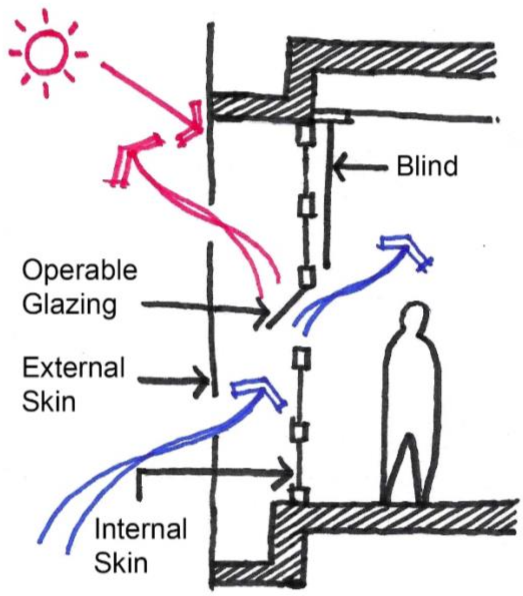


Figure 6. Diagram explaining the application of the DSF in Suasana PJH Building, Putrajaya (Author).

Next, installing shade devices improves the operation of the DSF in the tropics. The intense heat in the tropical climate region affects year-round, therefore a DSF without shade mechanisms may be inefficient in the tropics. According to Mohd Rodzi et al (2022), spaces near to the window possess a higher daylighting factor which contribute to higher daylighting, higher thermal comfort, and higher risk on glare. Thus, it is important to manage spaces near to the windows and the application of DSF can significantly reduce those effects. Based on the Figure 5 above, in this case study, the building includes extra shading mechanisms, particularly on the East-West façade, which receives the most direct sunshine. The temperature in the inner glass will rise if shading device is designed close to it. However, if the device is positioned in the middle of the cavity, the temperature will significantly reduce as the shading device prevent the direct hit gain to occur inside of the building. In this case, having both fixed louvers and solar operated blinds is preferable.

CONCLUSION

Based on the information obtained, analyzed, and reviewed, even though Double Skin Façade (DSF) may possess design difficulties and issues, the feature can perform well in tropical conditions. For this case study of Suasana PJH tower, DSF is practical and functional for tropical climate countries such as Malaysia.

If a building is entirely equipped with glazing material, the DSF plays an important role in reducing direct heat gain, lowering heat loss, and reducing running cost. However, well-designed, high-performance windows, such as double and triple glazing, can produce significant impacts. Fully glass façades will result in excessive daylighting on building's interior spaces and can cause glare unless the sunshine is carefully regulated and tempered. Careful consideration on design strategy for the glass facades for each circumstance is critical. These details play important roles in achieving goal and meeting the demand for DSFs.

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