Effectiveness of Double Skin Façade in Controlling Indoor Air Temperature of Tropical Buildings

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Abstract. Double Skin Façade (DSF) application on buildings envelope in tropical area aims to decrease cooling load of buildings. Generally, the system is applied on building in an extreme outdoors air temperature, so it could achieve a comfortable air temperature for occupants. This paper discusses effectiveness to control indoor air temperature of some DSF factors such as; 1) air gap between DSF and building façade, 2) glass type. For these purposes, collect outdoor, indoor and air gap air temperatures, surface temperature of all glass surfaces and indoor-outdoor globe temperatures. The initial results show an optimum setting of air gap and glass type of the DSF, as well as some guidance on glass type selection for building surface and DSF.

1. Introduction

Air conditioning system as an important part in building cooling strategies in tropical area consumes a lot of energy during the year [1]. Cooling load of the Aircon system comes from several aspects such as home appliance [2], human activities [3], however the biggest heat source is from outdoor-indoor heat flow at building envelope [4][5].

Energy consumption of building has been proved by many researchers that show big amount each year [5][6][7], the design of double skin façade on the building is construct to decrease this sector of its demands [7][8]. This system of façade is taken as an effective strategy to response dynamic thermal condition outside of the building and caused comfort thermal in indoor temperature [9]. This system defines by involving 2 layers between occupied space of interior and exterior environment which separated by an air gap [9] and one of the heat avoiding strategy, which this strategy is more effective than cooling strategy [10]. In certain size, this air gap could hold back the radiation which consist extreme temperature for entering indoor space and let it out [11].

Several researches referred in this paper has the states to define the role of double skin façade on the building. Aslim in her research explain that this system could play as retrofit strategy that relate to decreasing energy consumption over the building [12]. Dewi also states that double skin façade use air flow between the layers as a stack effect to decrease indoor temperature [13]. Darmayanty in her thesis report wrote based on the research that double skin façade could role as modifier which has design to confront heat outside of the building [14] Iyati also explain that double skin façade as an envelope for the building should use the wind as the potential for decreasing temperature on building surfaces [4]
Meanwhile the previous research by Aziiz shows that double skin façade revealed a larger distance managed to lower the temperature better than smaller distances because it delays the heat to entry the building, even the wind flow inside the gap have smaller wind velocity [15].

1.1 Application of Double Skin Façade
Many types of double skin façade system are created to applied for responding various thermal condition in a specific site around the world. One of the biggest percentage of DSF project has done in Northern Europe and Japan. This data shows limited research on another place such some tropical humid climate countries which has warm tendencies in thermal environment. This environment highly requires better cooling system to decrease energy consumption over the year.

However, the project in double skin façade has done several times, researcher found that in the summer time, overheating commonly occur in the air gap part of this system and cause increase of cooling load in the building [16]. Tropical-humid climate such as Indonesia has mostly high temperature throughout the year and there are only two season that is dry and rainy season. And those are cause its sun light intensity in all over the year. Research also states that the overheating risk on the system that applied in tropical country are high [17]. This air gap which design to prevent the extreme air temperature from outside environment must be configure specifically base on the environment case of each place.

The configuration of its size has been confirmed to define the behave of air flow for entering indoor space [18]. Research recently explain that the more bigger air gap is, the better it would prevent the extreme temperature from coming in. Research proved that this gap one of the vital part of the system which could defines the performance [15]. Many configurations such as this, and also the angle or the material we should provide are important to create best performance on this system [13].

In some cases, architects include shading devices in the air gap of double skin façade to responses solar exposure on the outer skin, so it would reflect out the radiation that brings heat to the indoor occupied space. In the other hand, configure the color of the shading devices that commonly called blinds is also considered recently to influence the radiation. This setting has a great result for decreasing the heat from coming in [19].

This research on the paper took Bandung as in Indonesia’s humid climate city to begin the experiment and to get the aims to control the temperature inside the building.

2. Model Testing Double Skin Facade
This paper involving a real scale model of double skin façade (figure.1) with adjustable air gap to investigate the ideal level of temperature indoor within its width 0.5, 1.0 and 1.5.

Figure 1. Research Aziiz, Wonorardjo, Koerniawan (2017) using real scale of model double skin façade with adjustable air gap.
This air gap easily adjustable only by user doing for research purposes and has a certain size of the existing part of the building in Bandung environment.

Figure 2. Illustration on research testing model with natural ventilation

In some cases, architects include shading devices in the air gap to respond solar exposure on the outer skin, so it would reflect out the radiation that brings heat to the indoor occupied space. In the other hand, configure the color of the shading devices that commonly called blinds is also considered recently to influence the radiation. This setting has a great result for decreasing the heat from coming in [20]. In this research on the paper provide one-way glass material as second layer of the system to make reflection effect, otherwise the color of this layer is dark bronze with reflection characteristic (figure. 3). So hypothetically it could decrease the heat in solar radiation that received by this layer which facing directly outside environment.

Type of ventilation for the system also allow to pull out the heat from the air gap before it entering inside [21]. This certain ventilation cause buoyancy effect which naturally driven the heat out of the system. On this paper researcher used open ventilation below the air gap system to make natural ventilation in every scenario (figure. 2).

Figure 3. One-way glass in second layer in the research as outer skin of the testing model.

3. Measurements Methods
This research present 3 kind of scenario that has the same material of outer material, that is one-way glass 5mm in dark bronze colour. To begin the testing, it is also involved model scenario for indoor environment to gain the temperature data in interior space by every scenario (figure. 4).

In this research, thermocouple devices were involved to measure the temperature value in certain spot (figure. 4). The measurements took 8 spot which consist 3 value of air temperature, 3 value of globe temperature, and 2 value of surface temperature. 3 air temperature will place on indoor, air gap and outdoor environment. So are the other 3 of temperature globe. 2 values of surface will take place on first skin of the system which seize clear glass and the other on the second skin that is one-way glass dark brown. Double skin façade generally must be ready-designed to facing the sunlight intensity
over the year with certain of humidity and wind condition. Some of the research are using simulation to use the wind as the potential to decrease the temperature surface on double skin façade.

![Diagram](attachment:image1.png)

**Figure 4.** measurements scenario in the research. Tg represent Globe Temperature, Ta represent Air Temperature, while Ts is Surface Temperature.

This several spots were defined to investigate the changes of temperature within every scenario and result comparison to see the most effective width with outer skin material one-way glass as a reflective layer.

![Device](attachment:image2.png)

**Figure 5.** measurements device in the experiment

The measurement device that is thermocouple will be used simultaneously to gain the data over the scenario (figure. 5). This device allows to measure 8 spot of temperature in one time, so that the authors would gain the same value with the same load condition in the field.

### 4. Research Analysis and Discussion

In this research, analysis of chart is presented to see the temperature changes and the differences with one spot of measurement and another. Researcher also involving software JMP 7.0 to investigate the latent pattern that could have not been show on the previous analysis, and produce analysis of correlation and analysis of variant.

#### 4.1 Analysis Distribution

The first analysis in this paper will be presented in a charts mode of diagram. This diagram directly inform the changes and the differences about the temperature value of each spot in measurements. This data contains value of Ta as the air temperature, Tg as globe temperature to see the value of heat
radiation in air temperature, and also Ts that is surface temperature that inform about the temperature of each layer of the skin.

The diagram below generally shows that there is indeed a temperature changes by the application of double skin facade system (Fig 6.). The changes are a decrease temperature in mostly each spot of measurements. Researcher use temperature globe (Tg) to see this decrease pattern because of its capability to show the value without others variables that might disturb the real value of the heat. And apparently the value of the temperature surface in every section and width of the air gap is also have the same decrease pattern tendencies.

![Figure 6. Comparison result in every section of the system, outdoor, air gap, and indoor. Tg represent Globe Temperature, Ta represent Air Temperature, while Ts is Surface Temperature.](image)

However, the decrease of the temperature is not quietly same in pattern. For example, the decrease pattern seems likely was not happening in temperature air in every width of the air gap. The width 1.5 and 0.5 has changes of increase temperature to the indoor section. In the other hand width of 1 meter is decreasing. This value of temperature in Ta spot in every section shows different pattern because of its variables that might happen in the measurement such as wind flow and air humidity that for exact it could make a change of its temperature.

The diagram also shows pattern of the 1-meter width of air gap. This width generally inform that 1 meter is happen to show the highest temperature of all. This pattern caused by the condition of the outdoor temperature when the measurement. However, if we look at the comparation of the differences between the outdoor temperature and air gap temperature (figure. 7), 1-meter width has the smallest changes. In the other word, these smallest changes of temperature mean that the capability of 1-meter scenario in the research is lowest than the other to prevent over heating in the air gap of the system.
Figure 7. Comparison result deviation in every width scenario on section Outdoor Tg to section Air Gap Tg. Tg represent Globe Temperature, Ta represent Air Temperature, while Ts is Surface Temperature.

In the data above also show precisely the smaller width produce highest changes which mean this scenario is so far, the best to prevent over heating in the air gap.

On the previous diagram (figure. 6), the changes of temperature are not showing some particular pattern, while 1 and 1.5 meter shows an increase changes of temperature to the indoor space, the 0.5-meter scenario shows a decrease change. So, from this data researcher could say that the scenario 0.5 meter of air gap could help cooling the indoor space.

In this paper researcher use one-way glass in every scenario as the outer skin or second layer that directly facing the outside environment. This layer will be rolled as reflectance layer from the solar radiation which contains heat.

From the diagram, it’s informing that the value of temperature in spot Ts (figure.6). this value shows the temperature of the surface and the changes between the second layer to the first layer by the temperature outside.

Generally based from the data, this material one-way glass as the second layer (outer layer) could help decrease the heat from outside environment. Its reflection characteristic helps to reflect the heat from sun light as electromagnetic wave that trying to transmit to the system.

Researcher using differences to show the capability of each width scenario to see which one has the biggest amount of decrease changes. It is again informing that scenario 0.5 has the biggest amount of decrease change in the surface temperature (figure. 8).

This result of analysis strengthens the argument that the 0.5 with one-way glass material scenario has the potential to be better in the double skin facade system. This biggest changes in the scenario 0.5 meter of air gap represent that the width allows material to decrease more than the other width.
Figure 8. Comparison result deviation in every width scenario on section Ts Second Layer Skin to section Ts First Layer Skin. Tg represent Globe Temperature, Ta represent Air Temperature, while Ts is Surface Temperature.

Researcher assume that this caused by the width itself. The bigger the gap, the smaller the changes to the other skin will be. The gap in the system allow the flow to move out to the other place. While the smaller gap applied, it will not have the same time to move out, and smaller gap makes the flow go faster than the other. That is why the decrease changes were not so much in bigger gap.

4.2 Analysis Correlation and Analysis of Variant
The second analysis would be using software JMP 7.0 to see the correlation between parameter which shown on each spot of measurement. For example, this analysis would investigate if there is any correlation between Ta outdoor to the Ta indoor, or if there is any direct influence between the width and the Ta indoor. The previous discussion in the previous analysis, research present several correlations between two same parameters or not. Same parameter would present in analysis of correlation, and the different parameter such as width and the temperature indoor (ta) would be present in analysis of variant.

Diagram below informing about the correlation between parameter Tg Outdoor and Tg Air Gap. This diagram value indicate significance which mean that the Tg in this spot as temperature outdoor given an effect for the Tg in air gap.

Diagram below also informing the trend of each measurement on the polynomial green. It is explaining that there is certain trend happen in these measurements
Generally, if there is an increasing value in Tg outdoor, the increasing also happens in Tg air gap. This trend happens until certain value of temperature. Based on the data, this trend will be slowing down and come back to increase.

Another information indirectly explains that most of the data are classified in one particular pattern which shown by blue circle. This blue circle is representing the reach of 90% data of all the measurements.

The next analysis would be presented on diagram of analysis variant. This analysis allows to compare two different parameters in the measurements. This analysis will include parameter the width and indoor temperature (Ta). These two parameters have different value which the width would represent 3 scenarios, and the other one represents value of temperature. So, this analysis would be informing the pattern of these parameter.

The analysis above indicate value of insignificant by the value Prob of 0.17 which it should be smaller than 0.1 to be significance. But the diagram informing about the result of the scenarios in the research. That is width of 0.5 meter has the best result for decreasing temperature indoor, and 1 meter of width shows opposite result.
Researcher assume that this significance value in the software caused by the width parameter would not affecting directly into indoor value. But experimentally, this result made differences.

5. Conclusion
The research came up with the ideal of how to controlling indoor temperature by using DSF system in the specific site in humid-climate country such as Bandung-Indonesia. The research providing real scale of model to be tested and resulting that this system also applicable to be use in tropical humid country to decrease heating inside the room. The recommendation in this research says that width 0.5 meter is the best scenario to reduce indoor air temperature. But this result only could be gain by providing outer skin one-way glass as a reflectance layer that directly facing the outdoor environment.

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