ANALYSIS ON THE EFFECTIVITY OF GLAZED DOUBLE SKIN FAÇADE IN PROMOTING INDOOR AIR MOVEMENT

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Abstract - There are many advantages of double skin façade, and thus it is applied widely in building design. One of the advantages is that the double skin façade presumably can deliver wind into the room. This study aims to investigate that specific advantage of the double skin façade. The research built a double skin façade prototype designated for high rise buildings. The prototype had already been studied in experimental and numerical manner. The study was in terms of surface temperature reduction due to the double skin façade installation. Hence, this study is a continuation of the previous work. This research use numerical method using Computational Fluid Dynamics simulation to model the air flow created by the double skin façade. The double skin façade is attached to a 5 x 5 m^2 room as the case study. Three schemes are simulated, which is differed only by the double skin façade's width. The results reveal a positive linear correlation between the wind speeds that enter the room to the double skin façade's width.

Index Terms - Buoyancy-driven ventilation, Computational fluid dynamics, Double skin façade, Indoor air movement.

I. INTRODUCTION

Researches state various methods and results due the difference location of double skin façade as it becomes a worldwide trend. This system simply provides an air gap between two layer or more that would detain excessive solar heat to enter the building [1][2], the heat avoiding strategy claimed to be more effective than providing cooling system [3]. There are several strategies to design this system on specific site cases, and the system can be applied both new and existed building [4]. Even though the system has proved to be an effective solution, the issues emergence in specific cases are continuing to be problem [5].

Europe with most of tempered climate regions has more variety standard as it will respond the extreme seasons through the year [6]. Many number of research state that this technology perform better in temperate, moderate and cold climate [7][8]. However, many tropic regions have not settled particular guideline regarding this matter and leaving a gap of standard, thus, further understanding is required [9][10][11][12][13]. Some of research inform to have ventilated design of double skin façade in tropic regions because its characteristic [14][15]. Since the presence of solar heat radiation are highly than the other regions, ventilated system are efficient[16]. Barbosa and Ip on their researches showed that this ventilated design of double skin façade common to use buoyancy driven and stack effect in air gap to improve air quality indoor [9][17][18][16][19]. Meanwhile, overheating in some of part of double skin façade such air gap and outer material continuing to decrease the performance of double skin façade in tropic region [20][21][22].

Although these topics was discussed and criticized since 1999 due the first report published, Dama in his research (2017) stated that there is still lack of innovation due the performance of double skin façade in many cases [23]. His research was likely putting on the model in controlled environment of experiment, this strategy was to provide a constant temperature on particular condition and very then using CFD to gain another result. The system of double skin façade in Dama's was design to respond the climate of Denmark.



Fig. 1. Tested real scale model of double skin façade on the field.

Therefore, the challenge in this works is to overcome the needs of information due the tropic climate in using double skin façade which took in Indonesia environmental condition. Authors designed a model real scale of double skin façade and using computer simulation by ANSYS Fluent to gain the results.

II. OBJECTIVES

This works aims to get scenarios of double skin façade even further with computer simulation following

experimental test on real scale model of double skin facade.

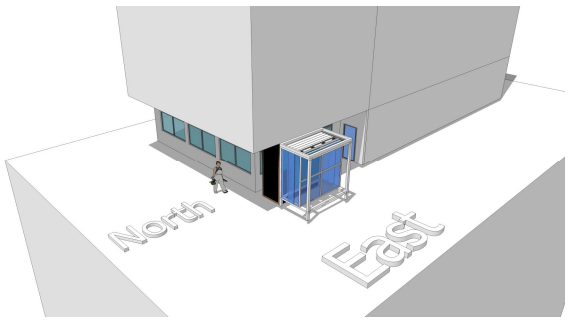


Fig. 2. Model's orientation on experimental test in the field

The first result gained by experimental with non-ventilated inner skin scenarios of double skin façade, these strategies generates certain results based on real environment of Bandung tropic climate. This stage was organized to obtain real parameters in the environment by designing double skin façade. The model was tested during transition period midst rainy to dry season on April to May. Several devices such an Anemometer and Thermocouple also involved.

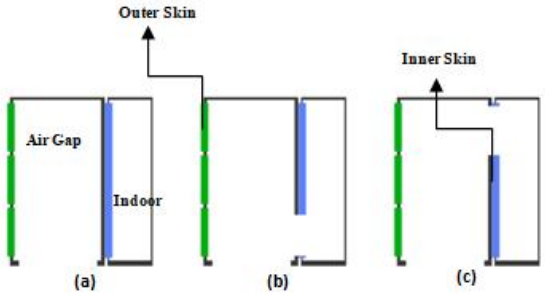


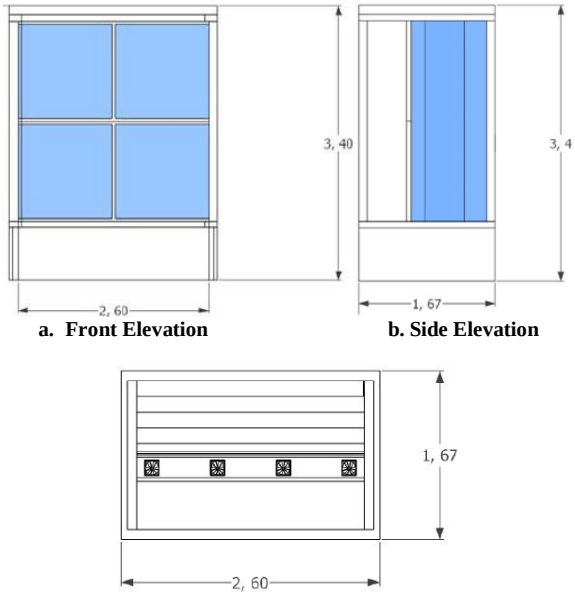
Fig. 3. (a) Original model of experiment, (b) First scenario on simulation shows down part opening in inner skin of the model, (c) Second scenario on simulation shows upper part opening in inner skin of the model.

Hereafter, the simulation begins with designing the same model design only it's ventilated. The ventilation was put on down part and upper part of inner skin in the system. This inner skin technically shall be the first skin of the building. Authors using ANSYS 15.0 to run the simulation that take further scenario for the system. Authors suspect that this ventilation could enhance the air flow on this system which could help cool down the air temperature inside.

On previous works that involved buoyancy-driven simulation on air gap scenario showed that the velocity which occur in this part of double skin facade doesn't define the temperature, whether its wider or narrower width of air gap. In this works, further scenario by means of providing ventilated part on inner skin to apprehend the air movement indoor was simulated to gain another result.

III. METHODS

This study employs numerical method by using Computational Fluid Dynamics. CFD software used is ANSYS Fluent. Geometry simulated in the CFD is a double skin façade for a 5x5 m2 room. The double skin façade (DSF) design is modelled as the prototype. Images in Fig. 4 show the shape and dimension of the prototype.



a. Front Elevation **b. Side Elevation**

c. Top View

Fig. 4. The prototyped double skin facade

The width of the DSF prototype is adjustable from 0.5 to 1.5 m. Outlets are located on the top side of the DSF. There are four square-shaped outlets with dimension of 15 x 15 cm.

Further, Fig. 5 displays the case study. This case study is a prototyped DSF attached to a 5x5 room. There are two openings in the wall between the DSF and the room. The lower opening has 90 cm height, started from the bottom part of the DSF. The top opening also has 90 cm height, measured from the top side of the DSF.

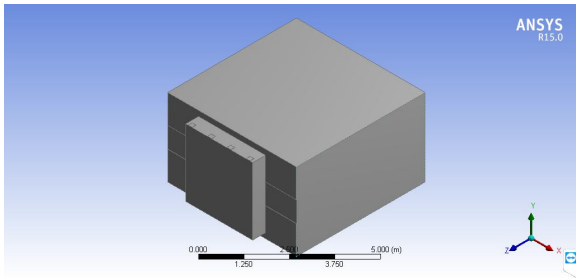


Fig. 5. Geometry of the case study.

Simulation for the case study is done for three conditions, which is differed only by the DSF's width. The three conditions are air gap width 0.5 m, 1 m, and

1.5 m. Measurement points are located at the lower opening as shown by Fig. 6.

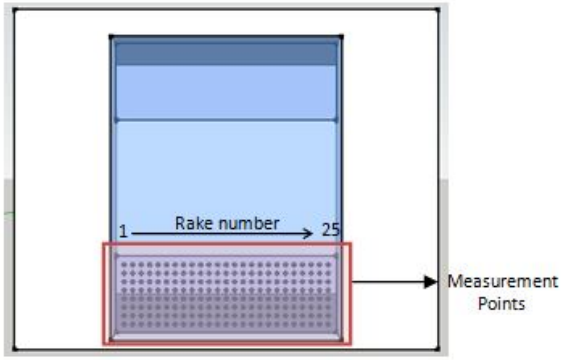


Fig. 6. Measurement location

Flow model of the case study is assumed as buoyanc-driven ventilation only. Thus, the Boussinesq approximation is used in the simulation. Boundary condition is set as shown by Fig . 7. Heat flux that generates the temperature difference and thus the buoyancy force comes from solar radiation. Bandung's radiation data is calculated using solar radiation calculation model, and the value for this particular case is 297 W/m2.

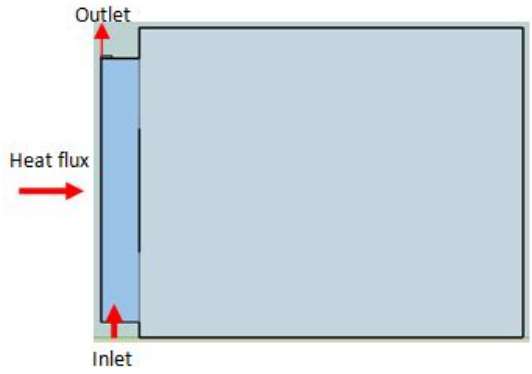
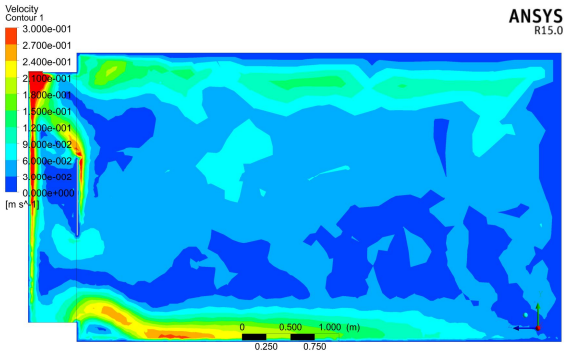


Fig. 7. Boundary settings

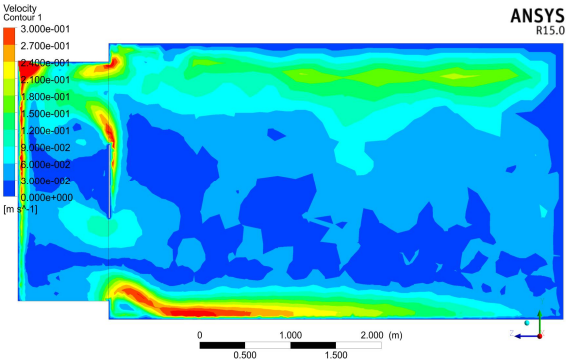
IV. ANALYSIS AND DISCUSSION

Simulation results of the three schemes for the case study are compared and analyzed qualitatively and quantitatively. Contour and vector image of the wind velocity is used to analyze the wind flow. Also, wind speed data at the measurement points aid the understanding of wind generated by the DSF. In this case, it is one of the simplest ways to analyze the relationship between the DSF gap and air movement entering the room.

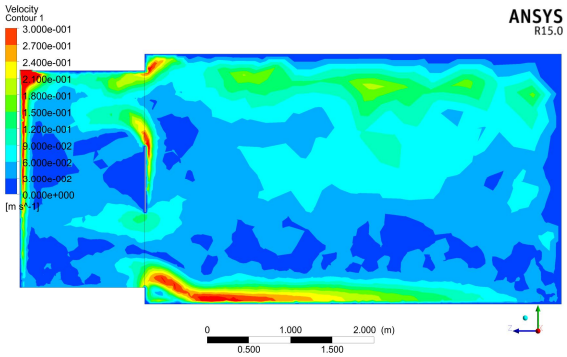
For the all DSF width scenario, air flows generated by the double skin façade enter the room as intended. Wind enters the room from the bottom opening and flows out from the top opening. This creates the air movement mostly at the lower level of the room as well as at the highest part of the room. Qualitatively, Images in Fig. 8 also show that the wider the gap of the double skin façade the higher the wind speed.



a. DSF width: 0.5



b. DSF width: 1 m



c. DSF width: 1.5 m

Fig. 8. Contour image of wind velocity

Deeper analysis on the wind speed generated by the DSF is shown by Fig. 9 and Fig. 10. Fig. 9 shows the distribution of the wind speed at each rake in the bottom opening for all of the three schemes. The figure also displays the average value for the schemes. The figure shows both the wind speed at each rake as well as the average value is higher for the wider air gap.

This confirms the previous analysis on the contour image of the wind speed. However, if the intended wind flow is at the seating or standing level, the flow pattern created from the case study seems undesirable. Nevertheless, it still can promote the air movement

inside the room, which is preferred than no air movement at all.

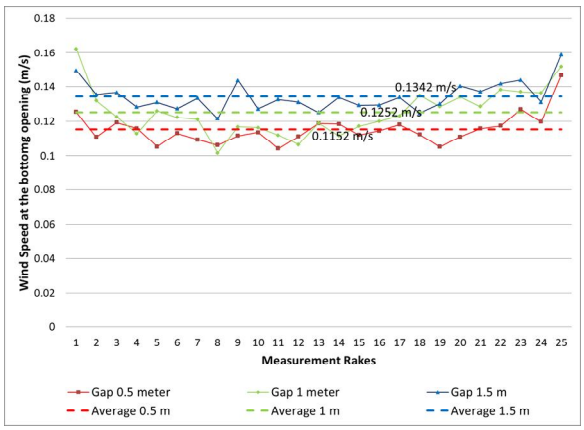


Fig. 9. Wind speed at bottom opening (inlet window)

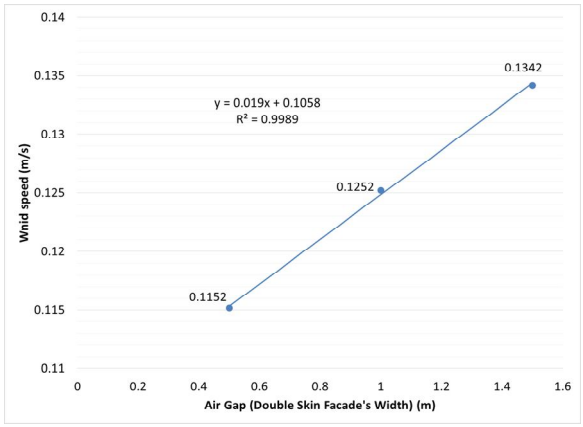


Fig. 10. Relationship between air gap (DSF Width) with wind speed generated at the opening

Further analysis can be done by comparing the value of average wind speed for each air gap or DSF width. The average wind speed values are plotted in Fig. 10. The reveals that there is a linear relation between the air gap in the DSF, or the width of the DSF, with the wind speed generated at the opening. In this case, for the bottom opening the relation is governed by the equation below:

$$v = 0.019\,x + 0.1058 \quad (1)$$

where: v = average wind speed at the opening (m/s)
x = DSF's width (m).

The resulting equation might be true for this specific case study only. Similar case study may need some adjustment in the constant value, yet it might still form a linear relationship.

In terms of architectural practice, the double skin façade prototype is expected to be applied in a high rise building. This is because the main cause of the buoyancy is heat flux from solar radiation. High rise buildings receive more solar radiation and have adequate temperature gradient to generate buoyancy effect.

Lessons from the simulation result for the real application of the DSF is that it should consider location of the openings in the façade's wall. This consideration is important to deliver the wind speed at the intended level (seating or standing position. Also, use the wider air gap, at least up to 1.5 m, in order to maximize the wind speed.

Further research is possible for this prototype. For example, the variable of the DSF can be added to glazing materials, inlet and outlet configuration, window's and DSF'S dimensions, etc. All of them can be done experimentally and/or numerically by Computational Fluid Dynamics.

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