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Innovative Breathing Facades Technology as a Solution for Building Energy Efficiency

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Abstract: The issue of energy efficiency in recent years has become an interesting topic. This is in accordance with assessments from several green building certification agencies in Indonesia and green building certification agencies from Malaysia (GreenRE, Green Building Index), as well as green building certification agencies from Singapore (BCA Green Mark) which gives each a maximum rating for energy efficiency points. The sector that contributes the largest energy consumption in the world based on data from the United Nations Environment Sectors is the building sector, around 35% in 2020, and in 2021 it will increase to 36%. In recent years high-performance "building envelopes" that integrate lighting, shading, and natural ventilation have the possibility to help reduce the energy used in building operations. Another factor caused by the building envelope system is to create visual effects and building aesthetics. This technology in some studies is called "facade breathing". The purpose of this research is to find a model that can flow wind according to standards and a model that can produce natural lighting according to standards. This research was conducted by simulation method. Simulation with Autodesk CFD to measure wind speed flowing into buildings. Simulation with Dialux Evo to measure natural lighting entering the building. The simulation results show that natural lighting, from the three degrees of opening (30°, 60°, and 90°) produces standard illumination above 50% in the room. The simulation results of wind speed also show similar results. The “folding umbrella" breathing façade consistently circulates air into the room between 40% -57% at all degrees of opening.

Keywords: Sustainable Architecture, Efficiency Energy, Breathing Facade

1. Introduction

The discussion on energy efficiency in recent years is very interesting for research and development. This is in line with assessments from several green building certification bodies in Indonesia and green building certification bodies from Malaysia (GreenRE, Green Building Index), as well as green building certification bodies from Singapore (BCA Green Mark) which give each a maximum rating for efficiency points. energy. In addition to the practical aspect (green tool), the discussion of energy efficiency has also been extensively researched in the academic realm, this has been proven by several articles.

The discussion on energy efficiency if pulled back will lead to the sectors that affect the amount of energy consumption and the factors that cause it. Based on data from the UN for the Environment, the sectors that affect energy consumption the most are the building sector, around 35%, then other industries at 32%, the transportation sector at 28%, and other sectors at 5%. In 2021, there will be an increase in energy consumption in the building sector to 36%, and in other sectors. However, the transportation sector and other industrial sectors experienced a decline [1, 2].

Several studies state that buildings contribute around 40% of world energy consumption [3-6]. The large use of energy in buildings is caused by several factors such as insufficient lighting [7], thermal comfort in buildings [8], uncontrolled solar radiation [9] the type of glass used [10], and the psychological influence of the user. building [11]. To overcome these problems, technology is used in buildings to help achieve comfort, such as the use of air conditioning, heating systems in cold climates, lighting systems, transportation systems, and other electrical systems.

According to research by Sharif S. and Hammad A., heating, ventilation, and air conditioning (HVAC) systems and lighting systems are responsible for 33% and 25% of the total energy consumption of office buildings, respectively [12]. Other research also states that the energy required for heating and cooling is 40%, water heating is 23%, other equipment is 17%, the refrigerator is 8%, lighting is 7%, and cooking is 5% [13]. Research conducted by Siamak Hosinzadeh states that energy consumption for heating ranks first, then energy for cooling, then lighting energy [14-17].

Efforts to reduce building energy consumption require a strategy that can help achieve this, starting from an active strategy to a passive strategy. Utilization of natural lighting is a sustainable method for controlling the flow of natural light [18-20], placing courtyards in building designs [21], using energy-efficient ventilation [22], applying horizontal grids and overhangs [23] building wall materials that can control thermals [24-26], the use of window glass materials [27]. Another strategy is in the form of solar power plants [28-30]. The use of smart windows is also one of the strategies to reduce building energy consumption [17, 31-33].

Based on the explanation above, a high-performance building “envelope” that integrates natural lighting, shading, and natural ventilation systems, can reduce the energy used by building operations. In addition, the building envelope can also create an important component of the visual effect and aesthetics of the building. This technology in several studies is referred to as a breathing façade. Breathing Façade is a building facade system that can control solar radiation and airflow from outside the building to create comfort inside the building, as well as using innovative materials and systems to efficiently contribute to the building's energy use.

Before the term breathing façade, several facade systems had developed with similar definitions and ways of working, including adaptive façade, active façade, advanced façade, kinetic façade, intelligent façade, interactive façade, responsive façade, and smart façade. What makes this facade different from other breathing façades is innovative materials and systems that efficiently contribute to building energy use, but in this study, only two assessment indicators were simulated to find the most efficient facade system in reducing building energy consumption. The simulation carried out is a simulation to determine the wind speed that passes through each model of breathing façade as well as a simulation of natural lighting.

2. Research Methods

This study uses a quantitative method through simulation to compare several alternative facades that are most efficient in reducing building energy consumption. The simulation uses the Dialux Evo application to simulate natural lighting. The simulation process is carried out by placing several alternative facades alternately in the model, and then comparing the average amount of lighting in each room. To find out the ability of the facade model to flow wind, the model is simulated in the Autodesk CFD application. After that, the simulation results were collected and then written in the research report.

3. Result and Discussion

3.1. Facade Basic Forms

The basic form of the facade that is used as a simulation model comes from the results of precedent studies on 4 buildings. The first model comes from two buildings with a facade that can fold horizontally, namely the Kiefer Technic Showroom building in Austria and the CJ Blossom Park building in South Korea. The second model is a facade system that folds vertically like the facade used by the Kolding Campus building in Denmark, and the third model is a facade system that works like an umbrella (all axes can fold) like the building facade system at Al-Bahar Tower in Abu Dhabi.

3.1.1. Horizontal Folding Model

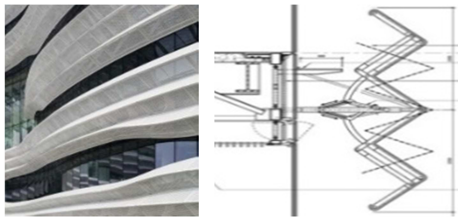


Figure 1. *The facade of the CJ Blossom Park building,*

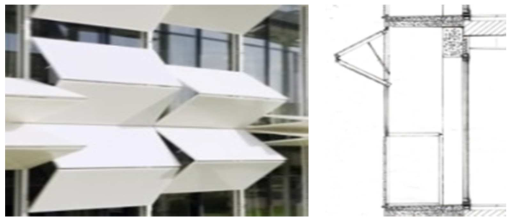


Figure 2. *Facade of the Kiefer Technic Showroom building.*

3.1.2. Vertical Folding Model

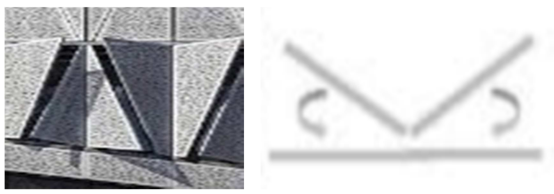


Figure 3. *Kolding campus building façade.*

3.1.3. Umbrella Folding Model

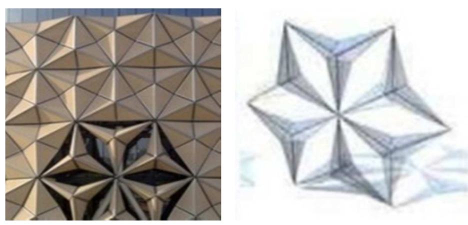


Figure 4. *The facade of the Al-Bahar Tower building.*

3.2. Framework for Development of Breathing Facades Design Test Model

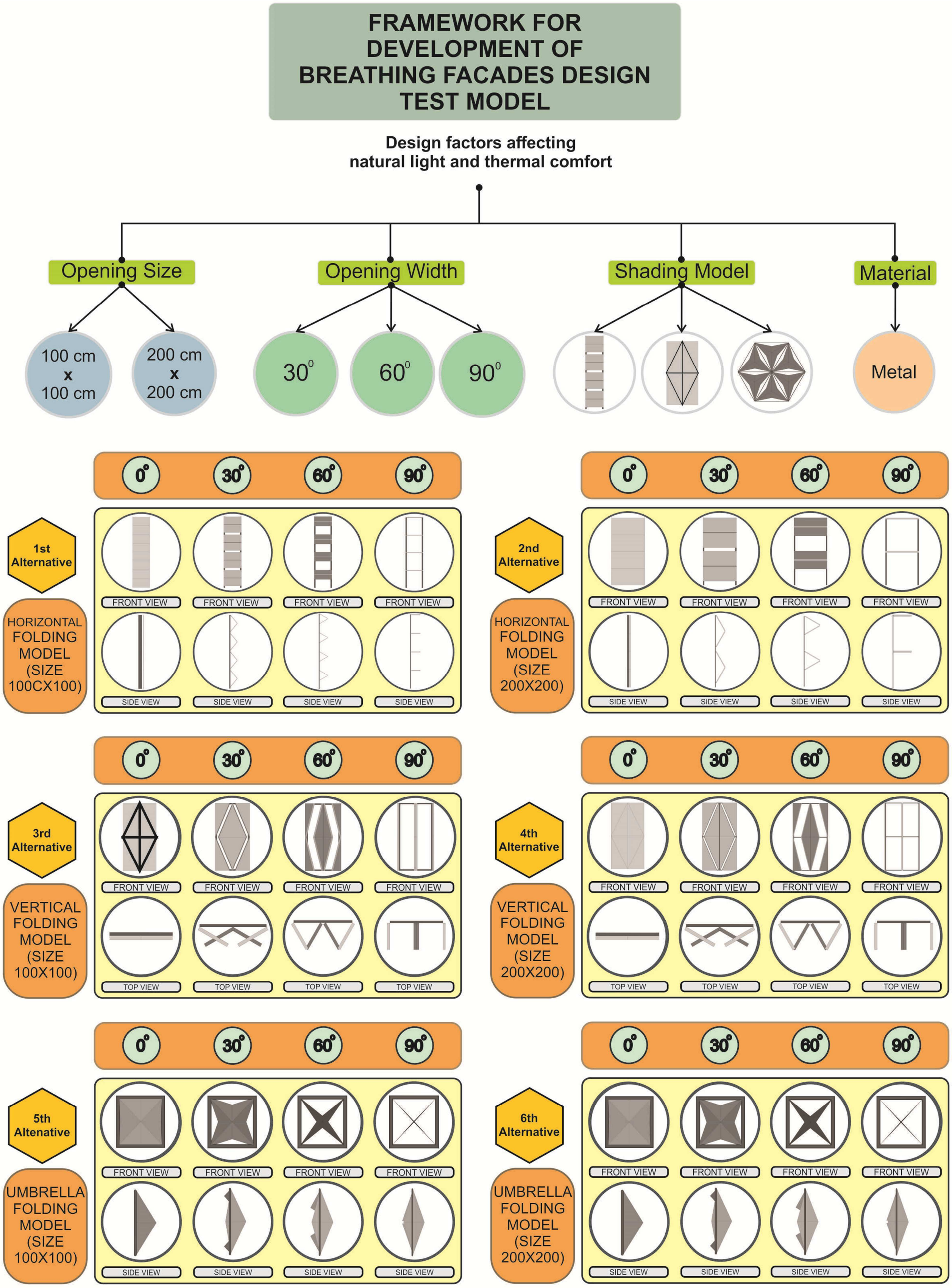


Figure 5. *Framework for Development of Breathing Facades Design Test Model.*

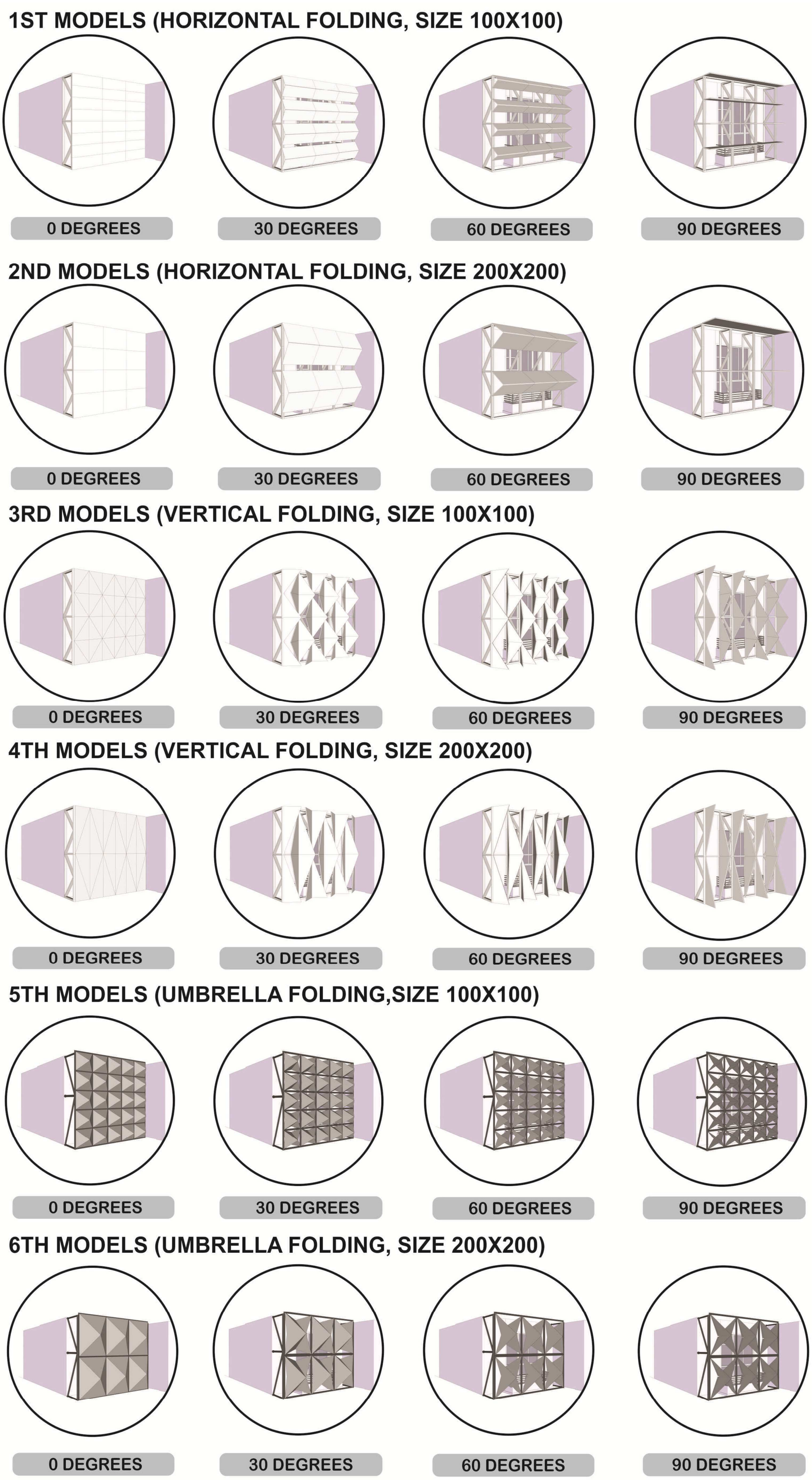


Figure 6. *Application of the Breathing Façade Model in Building Models.*

3.3. Model Description for Simulation

The model used as the test sample is a 4 m x 6 m room whose orientation is made to face east so that each alternative model of the breathing façade can be placed on the east wall.

3.4. Sustainability Assessment Indicators for Breathing Facades Technology

Determining the sustainability assessment of technology must always be based on the three pillars of sustainability (economic pillars, environmental pillars, and social pillars). Referring to Research conducted by Saeid Habibi, et al. mentions several variables in assessing the sustainability of technology, including the economic aspect, The variables being assessed are fabrication and assembly costs, maintenance costs, operating costs, and dismantling costs. In terms of environmental aspects, the variables include the amount of energy consumption, the amount of energy efficiency, the amount of annual absorbed emissions, the materials used can be recycled, the materials can be reused. On the social aspect, several variables include the flexibility of the breathing façade system, ventilation performance, and natural lighting, as well as user safety factors [34].

The results of this study were developed into indicators that can help measure the sustainability of the breathing façade technology. Some of the indicators being assessed are the ease of procuring materials, ease of maintenance, cost of dismantling and disposal stages, as well as the amount of annual energy consumption after the breathing façade is installed. Assessment indicators on environmental aspects include U-value material, OTTV value, and the amount of energy saved after the breathing façade technology is installed. On the social aspect, the assessment indicators include the assessment of thermal comfort, quality of wind flow into the room, quality of natural lighting in the room, as well as material resistance to temperature, weather, and fire resistance.

In this study, the process of measuring the sustainability of the breathing façade technology was only carried out by simulation to measure the quality of airflow into the room, as well as the quality of natural lighting in the room after several alternative models of breathing façade were installed.

3.5. Simulation Results

3.5.1. Natural Lighting Simulation

The natural lighting simulation uses the DialuxEvo application, The time setting for the simulation is determined at noon (12 PM) with average sky conditions and the implementation date is February 22. Still, for the location, due to limited choices in the application, the city of Jakarta was chosen.

Table 1. *Visualization of natural light simulation results on a model with an open BF of 30°.*

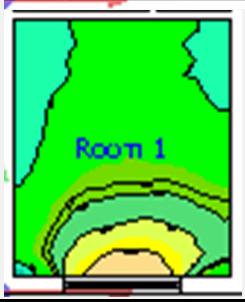
Type of BF	Size 100cmx100cm	Size 200cmx200cm
Vertical Folding Model		
Horizontal Folding Model		
Umbrella Folding Model		

Table 2. *Visualization of natural light simulation results on a model with an open BF of 60°.*

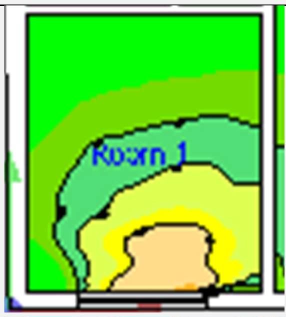
Type of BF	Size 100cmx100cm	Size 200cmx200cm
Vertical Folding Model		
Horizontal Folding Model		
Umbrella Folding Model		

Table 3. *Visualization of natural light simulation results on a model with an open BF of 90°.*

Type of BF	Size 100cmx100cm	Size 200cmx200cm
Vertical Folding Model		
Horizontal Folding Model		

Type of BF	Size 100cmx100cm	Size 200cmx200cm
Umbrella Folding Model		

Table 4. Percentage of room area that gets irradiation according to standards (>300 lux).

Type of BF	Percentage of area exposed to natural light (%)		
	30°	60°	90°
Horizontal Folding Model (Size 100x100)	79,375	68,194	9,1667
Horizontal Folding Model (Size 200x200)	77,083	62,847	43,889
Vertical Folding Model (Size 100x100)	81,875	70,139	60,347
Vertical Folding Model (Size 200x200)	74,375	62,847	47,708
Umbrella Folding Model (Size 100x100)	79,167	70,833	63,403
Umbrella Folding Model (Size 200x200)	47,708	67,361	47,708

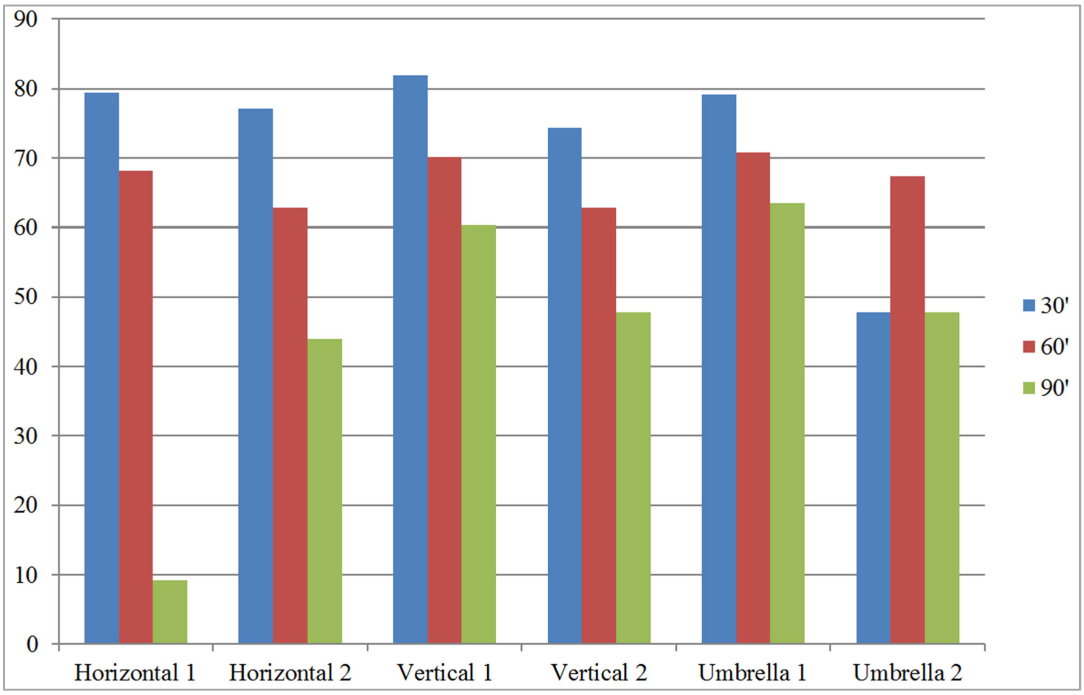
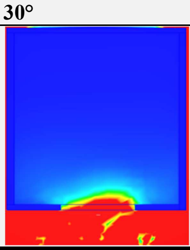
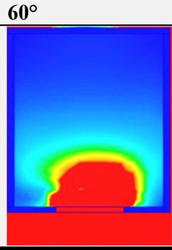
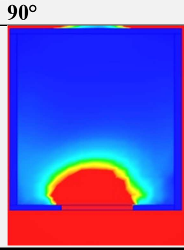


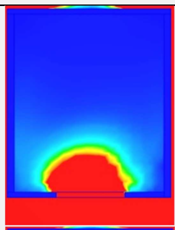
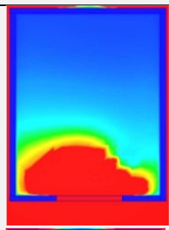
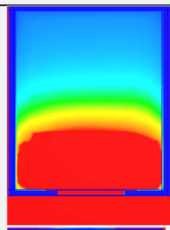
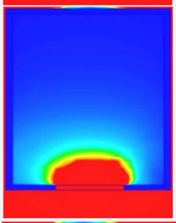
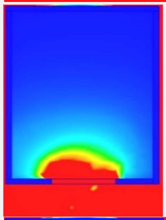
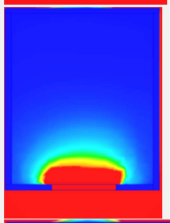
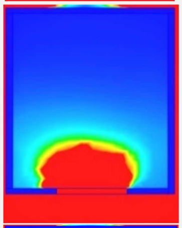
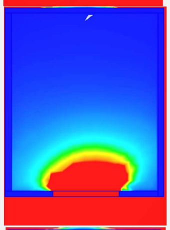
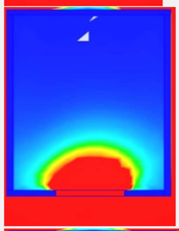
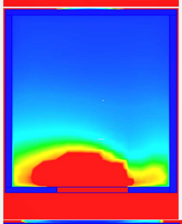
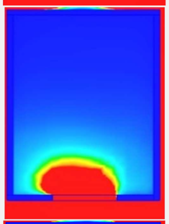
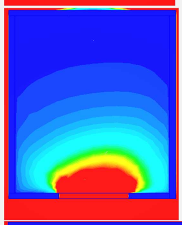
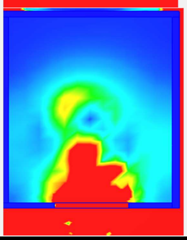
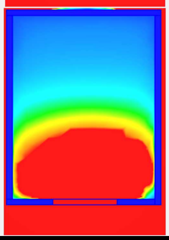
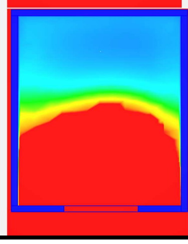
Figure 7. Percentage of areas that get natural lighting according to standards.

3.5.2. Wind Speed Simulation

Wind speed simulation using the Autodesk CFD application. The wind speed condition is set at 3 m/s to get a clear visualization of the simulation results.

Table 5. Visualization of wind speed simulation results on models with an open BF of 30°, 60°, and 90°.

Type of BF and Size	30°	60°	90°
Horizontal Folding Model (Size 100x100)			

Type of BF and Size	30°	60°	90°
Horizontal Folding Model (Size 200x200)			
Vertical Folding Model (Size 100x100)			
Vertical Folding Model (Size 200x200)			
Umbrella Folding Model (Size 100x100)			
Umbrella Folding Model (Size 200x200)			

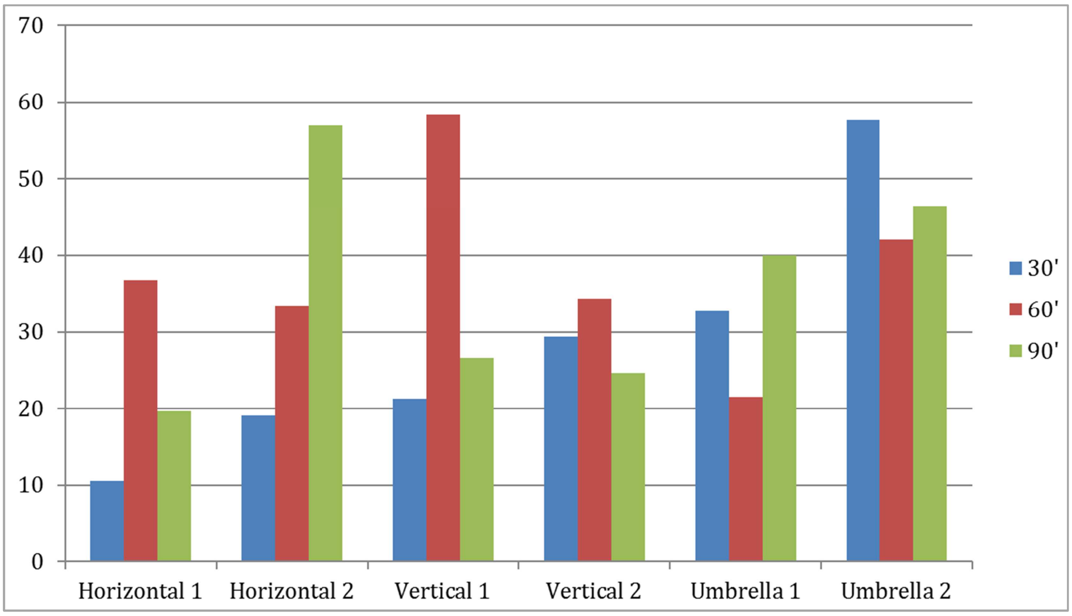


Figure 8. *Percentage of areas that get wind flow according to standards.*

Table 6. *Percentage of room area that gets wind flow according to standards.*

Type of BF	The percentage of the area of the room that gets wind flow (%)		
	30°	**60°**	**90°**
Horizontal Folding Model (Size 100x100)	10,6042	36,7361	19,7222
Horizontal Folding Model (Size 200x200)	19,1667	33,4722	56,9444
Vertical Folding Model (Size 100x100)	21,3194	58,3333	26,6667
Vertical Folding Model (Size 200x200)	29,375	34,3333	24,6528
Umbrella Folding Model (Size 100x100)	32,7083	21,5278	40
Umbrella Folding Model (Size 200x200)	57,6389	42,0833	46,5278

4. Conclusion and Recommendations

Based on the simulation results of the two indicators tested, including the quality of natural lighting and indoor wind speed, the breathing façade model that can be said to be superior is the breathing façade model which folds umbrellas. The simulation results show that natural lighting, from the three degrees of opening (30°, 60°, and 90°) produces standard illumination above 50% in the room. The simulation results of wind speed also show similar results. The breathing façade model that folds umbrellas consistently circulates air into the room between 40% -57% at all degrees of opening.

The drawback in this study is only three degrees of opening were tested (30°, 60°, and 90°), which should be based on the definition of breathing façade technology, each model should be able to fold from 0° to 90° which can adapt to the surrounding climatic conditions to provide comfort for building users. Recommendations for future researchers are to continue and develop simulations of various facade models at several degrees of opening, analyze the materials used, and deepen the study of three aspects of sustainability (economic aspects, environmental aspects, and social aspects).

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