Effects of Cavity Depth of Glass Facades on energy performance of the office building facade scenarios of Dhaka City, Bangladesh

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Abstract

The concern of warming brought on by extreme solar radiation entering the glazed façade may become serious in Bangladesh, where high-rise buildings now commonly use these systems. This scenario will lead to higher energy usage since there will be a greater requirement for electricity to cool the indoor environment. Determining the effects of the Cavity Depth of Glass facades on the energy consumption of office buildings in Dhaka, Bangladesh, is the primary goal of this study. To establish techniques for optimization, different cavity depths, and other glazed façade system parameters have been proposed. Results were obtained by modelling the variables of the investigation using the computer simulation software EnergyPlus. As per the findings of the study, glazed façade systems in Dhaka may benefit greatly from a cavity depth of 1000 mm combined with bronze laminated glass. The glass façade's thermal performance is enhanced under the ideal cavity system since there is a discernible drop in the building's annual end-use energy of about 12.28 % and a drop in indoor temperature of roughly 2°C.

Keywords: Cavity Depth, Annual Energy Consumption, Glass Façade, End Uses, Cooling load

1. Introduction

The rising breadth of environmental evaluation in performance assessments may be considered as a progression from a single criterion examination, such as the economic performance of buildings, to a complete integration of all concerns happening over a building's lifetime and its components. Thus, it is evident that "Sustainable Buildings" is a broad, multi-criteria topic relating to three fundamental interrelated factors: economics, environmental concerns, and social dimensions. (Giama 2009, William 2011) Additionally, modern structures and their HVAC systems must now adhere to an ever-cumulative need for improved execution in terms of comfort as well as financial and environmental concerns. They must be more energy efficient as a result. By 2020, the use of energy-efficient building design techniques can reduce energy usage worldwide by 34%. (Expert Group on Energy Efficiency 2007, Rana et al., 2022).

Bangladesh's development is due to its status as a developing country and the fast-growing industries and technologies there. Due to the increase in demand, the country is currently undergoing an energy crisis. Energy demand and supply are becoming more and more at odds with one another. (Sharif Ullah

Al-Mamun et al., 2021) Due to the collective demand for office space in the congested urban environment, office buildings around the world, including Dhaka, have changed from low rise to high rise. One distinguishing characteristic of Bangladesh's recent tall office building development is the significant use of glass. Installing curtain glass envelopes over large openings is currently the most common solution. This enhances aesthetic appeal while also providing the occupants with views and natural light. (Trisha, 2015).

400 KWh of power are used per person per year in Bangladesh. Only 40% of the 160 million people in the country have access to power. About 40 to 45 percent of the nation's electricity is used in the metropolis of Dhaka (Istiaque & Khan, 2018). Instability in the global energy market and a rise in import cost due to a dollar price hike brought back rolling blackouts to Bangladesh in mid-2022 and the government hoped the situation would improve by the end of September, but it has rather worsened into the second week of October. (Bdnews24, October 2022).

However, neither the Bangladesh National Building Code (BNBC) nor any other published rules in our nation contain any standards pertaining to the thermal performance of office envelopes.
The power crisis is everywhere which is creating discomfort in many ways for the users, mostly thermal discomfort. Simulated analysis of the thermal performance of a building envelope can be a useful tool. (Tzempelikos, 2007) and the method can be used to achieve thermal comfort in office buildings.

2. Literature Review

2.1 Building Envelope

The building envelope is the actual barrier that physically divides a building's internal and external environments. (Wang, J., & Hagentoft, C. E 2001). Many components and systems that make up the building envelope shield the interior space from environmental factors such wind, precipitation, temperature, humidity, and UV radiation. The internal environment is composed of the occupants, furniture, construction materials, lighting, machinery, equipment, and HVAC (heating, ventilation, and air conditioning) system. (NIBS 2012) Modifying the building envelope is a highly effective way to improve a facility's energy efficiency. Choosing a suitable external envelope is an important decision in the architectural design process because of its complexity and hyper-interfering qualities. (Khadraoui et al., n.d. 2021 ,Manioglu & Yılmaz 2006; Ibañez-Puy et al. 2017).

2.2 Glazed Façade

The French term that originally meant "front face" is where the word "Façade" originated. (Taywade and Shejwal, 2014). A glazed façade, often known as a "curtain wall," is typically installed vertically on the outside of a building with the purpose of shielding the building and its occupants from the extremes. (CPNI, 2019). The glazed façade is an external, non-load-bearing wall that typically drapes from the building like a curtain and is attached to the floor slabs. It only supports its own weight; the structure doesn't force it to carry any dead loads. (Halawa et al., 2018).

The whole external surface of the glazed facade is made of glass, however other cladding options include stone and aluminum panels. For optimal natural illumination inside the building, the heavily glassed front is designed to be transparent, light, and airy with more daylight access. (Poirazis, Blomsterberg and Wall, 2008). Glazed façade is becoming more and more prevalent in modern structures because of its excellent light transmission and good outside view for the occupants. (Liu, Wittchen and Heiselberg, 2015).

2.3 Classification of Glazed Façade

Usually, transparent, or clear glazing materials are encased in a metal frame to form the glazed façade. (Halawa et al., 2018). The number of panels, tinting, low-emission coatings, and different frame materials used in glazing projects all influence the façade's thermal efficiency; however, glazed façades have less thermal insulation than opaque façades. Glazed façades are now more commonly used in most high-rise buildings to enhance visual comfort and enhance building efficiency (Aksamija, 2016). Additionally, when the space between the glazed layers is naturally or artificially ventilated, glazing facades can lessen the thermal heat absorption from direct and diffuse solar radiation (Touma and Ouahrani, 2017). Single glazing façades and double-glazing façades, also referred to as double skin façades, are the two types of glazed façades (DSF).

2.3.1 Single Glazed Façade

This category includes glass building skins composed of a single glass panel, whether they are laminated, insulated, or single glazing. For transparency, single glazed façade was employed to produce many building facades. The rate at which heat transfers through a building's façade is determined, however, by how well it can control heat transmission, especially considering the size (Aksamija, 2016).

2.3.2 Double Glazed Façade

Double glazing or a double skin façade is a building façade with several glazed façade skins covering one or more layers and divided by an air gap and airflow between the two skins of the façade within the hollow (DSF) (GhaffarianHoseini et al., 2016). Between the two layers of DSF, the air gap serves as an insulating barrier to keep out substances that can reduce indoor comfort. The gap's secondary function is to provide an external wall temperature buffer that can be exposed to the components through mechanical or natural ventilation of the cavity, hence reducing the HVAC system's energy consumption. (Halawa et al., 2018). In high-rise structures in particular, DSF may cover full-height windows to protect the indoor environment while improving lighting, energy conservation, and heat gain.

2.4 Technical Information About Glazed Façade

In addition to ensuring user comfort, the building's exterior should portray the object's character. Therefore, for façades, outside glass is offset from interior glazing for the outer skin, air cavity, and insulation layer (Balocco, 2002). Sufficient apertures in both the outer and internal layers provide natural ventilation in the voids and inner spaces next to the façade. Shading devices were also introduced into the air channel to lessen the cooling load caused by the high quantities of solar radiation in indoor spaces (Zhou and Chen, 2010). Throughout the conceptual design process, passive design strategies such as glazed façade technologies must be integrated into building envelopes by identifying and managing aspects that significantly affect building performance. Heat transfer, the depth of the cavity, and the type of glass used all affect how well the glazed façade performs.

2.4.1 Depth of the Cavity

The cavity depth can be adjusted for optimal performance based on the different plans for using the glass façade. According to Ding et al. (2005), previous research indicates that the channel or air cavity depth should be within the range of 80 to 100 cm. However, according to BBRI (2002), which Brown (2016) cited, air cavities must have a depth range of 100 mm to 300 mm or even up to 2000 mm. In addition to maintenance, the cavity depth has an impact on greenhouse effects, ventilation, and energy efficiency (Joe et al., 2014).

According to Rahmani et al. (2012), optimizing the cavity depth and glass composition minimizes solar heat gains, which improves façade features. The effect of cavities ranging in depth from 8 to 148 cm demonstrated that the range is less dependent on cavity depth than the style of window glazing. By altering the cavity's initial depth from 148 to 78 cm, comparable drops in heating, increases in cooling, and reductions in total energy consumption were achieved (GhaffarianHoseini *et al.*, 2016).

The quantity of energy used indoors can be greatly influenced by the thermal properties of a building's cavity that is paired with a glazed façade, depending on the climate and constraints. It is directly related to the adjacent conditioned zone's need for heating and cooling. Therefore, in determining the proper cavity depth, the climate of the area where the building is located must be considered (Joe *et al.*, 2014). (Ghaffarian Hoseini et al., 2016) asserts that when choosing the ideal double-skin façade, variables including temperature, the cost of window glass, and various illumination energies should all be contemplated.

2.4.2 Types of glass for a glazed façade

The skin of the façade is defined by Arons and Glicksman (2001), cited by Brown (2016), as two flat components that permit air to flow through the system from the inside as well as the outside. Terri Boake (2003), cited by Brown (2016), states that the façade consists of two glass skins connected by an air corridor, demonstrating that glass is the only material that can create a highly glazed exterior.

For glazed façade designs, solar control glazing and clear low-emissivity (low-e) coatings are additional options to transparent glass. Additionally, studies show that different glazing types have unique thermal characteristics and energy-related behaviours that vary depending on the kind of window glazing (Joe et al., 2014).

2.4.3 Shading Devices

Prioritizing the shading devices is necessary since glazed windows are the primary source of incoming heat infiltration and a factor in the risk of overheating (Datta, 2001). Previous studies have shown that in order to optimize energy savings, large glass facades must properly integrate and assess shading components early in the design process (Kirimtat et al., 2016). Applying the proper shading devices and positioning them correctly in respect to the façade orientation will maximize the reduction of solar heat. This is because different layouts have varying effects on energy savings and thermal performance. Wong & Li(2007) estimate that horizontal shade devices may be able to cut cooling load energy by 2.62–3.24 % in hot and humid weather.

3. Methodology

Figure 1 depicts a typical office building in Dhaka city, which served as the study's base case model. A summary of the building is provided in Table 1. Three categories were used to examine the building's energy efficiency to establish the ideal Cavity Depth configuration. Version 22.2.0 of the EnergyPlus software was utilized to simulate the overall energy consumption and for cooling purposes. The interface of the office building under study was modeled using Google SketchUp 2022 and the OpenStudio plugin, as shown in Figure 2.

Table 1: Building description.

Description	**Remarks**
Number of floors	14
Gross floor area in total	3295^2m
Floor-to-floor height	3m
Occupancy load	Average 10 person/m^2
Roof material	RCC Slab of 150mm
Internal floor and ceiling material	150 mm RCC slab with Gypsum False ceiling in some floors
External glazing	Single-glazed, blue-tinted mercury glass on the front façade, facing slightly southeast
Outside Walls	127 mm Brick Plastered Wall on the other sides
Indoor Temperature	31°C
Air-conditioning system	The overall building does not have a separate air conditioning system. While some levels use a VRF system, the majority of the stories use windows and split-type air conditioning.
Lighting system	General Lighting
Working day	Saturday-Thursday
Schedule of operations	9.00 am- 6.00 pm
Weather data	Dhaka

Figure 1: Base case building, Dynasty Wahed Tower.

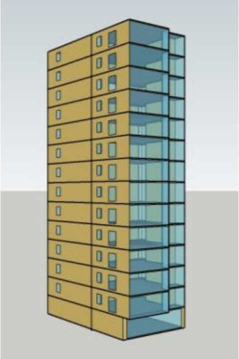


Figure 2: Energy modelling of base case building

The goal of this study was to identify the optimum glazed façade cavity depth. Three modifications in cavity depth are proposed in order to maximize this approach and assess its effectiveness in fitting a double skin façade to the building. Three different cavity depths—500 mm, 1000 mm, and 1500 mm—are being suggested based on its category. Table 2.

Table 2: Different types of Cavity Depth for Glazed Façade

Category	**C-1**	**C-2**	**C-3**
DSFs configuration	**Multiple-storey DSF**	**Multiple-storey DSF**	**Multiple-storey DSF**
Ventilation mode	**Natural ventilation**	**Natural ventilation**	**Natural ventilation**
Cavity depth	**500mm**	**1000mm**	**1500mm**
Internal glass	**Bronze laminated glass**	**Bronze laminated glass**	**Bronze laminated glass**
External glass	**Clear e-glazing**	**Clear e-glazing**	**Clear e-glazing**
Shading device	**No shading device**	**No shading device**	**No shading device**

4. Results and Discussion

2.5 Annual Energy Consumption

Figure 3 shows the study's final outcome. Based on the cavity depths, the chart shows that there is a slight variation in each category. Comparatively speaking, the façade cavity with 1000 mm has the lowest annual end uses and cooling building energy consumption, at 368309 kWh and 195220 kWh, respectively. However, a cavity with a depth of 1500 mm has the highest annual end energy consumption (370264 kWh) and cooling energy (198002 kWh).

Furthermore, it is clear that the least energy-consuming DSF has a 1000mm cavity depth (C-2); it may save roughly 51106kWh of energy annually, or 12.28%. (Table 2). Furthermore, Figure 3 depicts the related changes in cooling energy based on cavities. The cooling energy from 195220kWh to 222550kWh is marginally higher than that of the basic case model, but it does not differ substantially between category C-2 and C-3 with 195220kWh to 198002kWh. Consequently, the category C-2 could save 27328kWh of cooling loads annually.

Figure 3: Annual end uses and cooling energy of DSF with different cavity depth, [kWh]

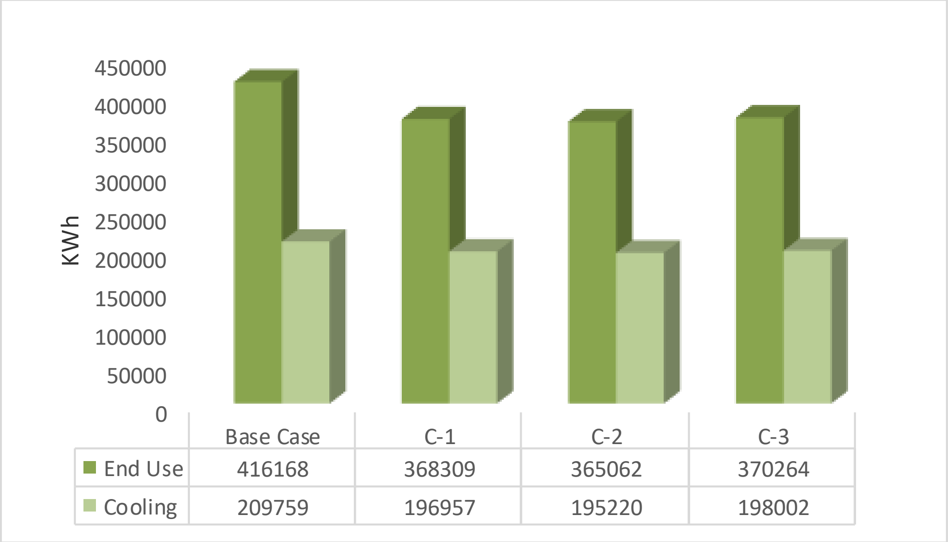


Table 2 **Annual end use energy [kWh] and Annual saved energy [kWh], [%]**

Category	Base case	C-1	C-2	C-3
Annual end use energy [kWh]	416168	368309	365062	370264
Annual saved energy	[kWh]	47860	51106	45903
	[%]	11.50%	12.28%	11.03%

Because the annual electricity demand of buildings with DSF has dropped dramatically compared to the base case scenario, this study indicates that DSF offers significant potential for improving energy consumption conditions for office buildings in Dhaka City. All of the DSF categories in this study, of course, have the potential to reduce overall annual energy use by an average of 11.6 %. (Table 2). For categories C-1, C-2, and C-3, monthly end uses, and cooling energy are shown in Figures 4, 5, and 6, respectively.

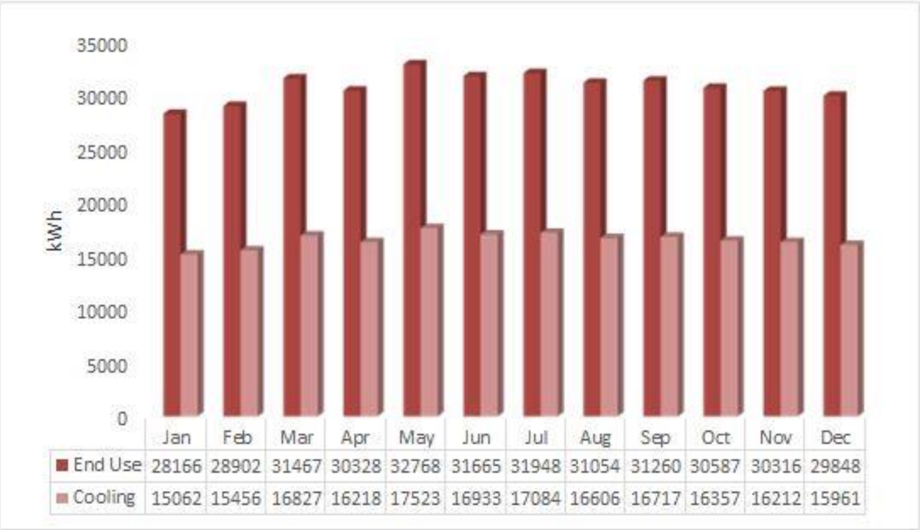
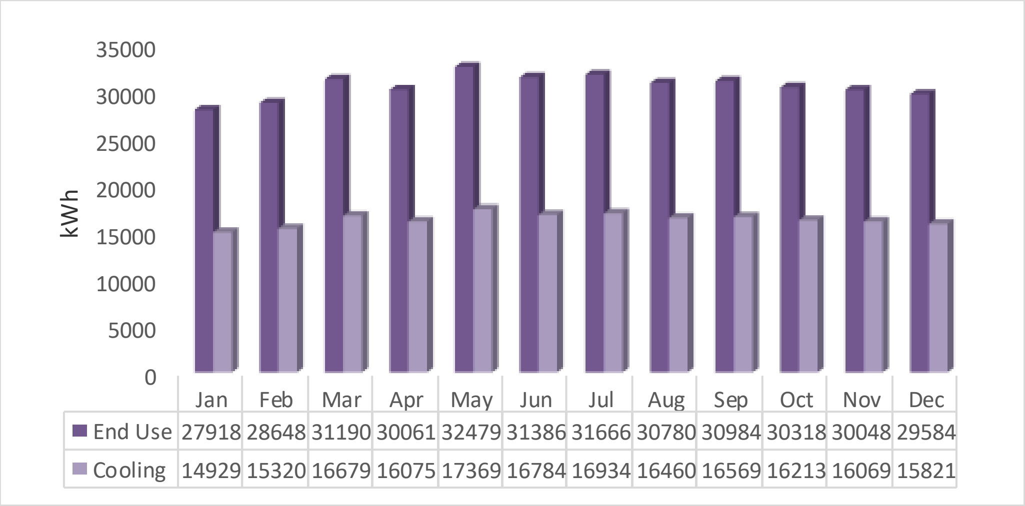
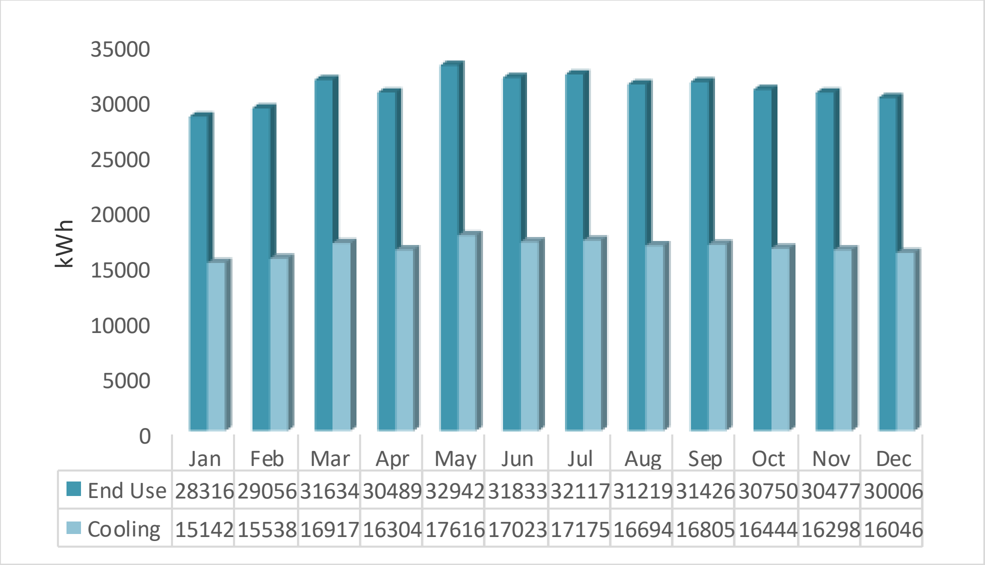


Figure 4: End uses and cooling energy of category C-1 on Monthly basis, [kWh]



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
End Use	27918	28648	31190	30061	32479	31386	31666	30780	30984	30318	30048	29584
Cooling	14929	15320	16679	16075	17369	16784	16934	16460	16569	16213	16069	15821

Figure 5: End uses and cooling energy of category C-2 on Monthly basis, [kWh]



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
End Use	28316	29056	31634	30489	32942	31833	32117	31219	31426	30750	30477	30006
Cooling	15142	15538	16917	16304	17616	17023	17175	16694	16805	16444	16298	16046

Figure 6 End uses and cooling energy of category C-3 on Monthly basis, [kWh]

5. Conclusion

By decreasing the yearly end-use and cooling energy requirements in the building under study, the study's findings demonstrate how optimal Glazing Façade Cavity depth improves energy performance. However, to prevent unforeseen problems with building envelopes like extensive solar radiation and heat transfer into the area, a well-designed glass façade is necessary. For office buildings in Dhaka, the suggested cavity depth design is 1000 mm to achieve a minimum annual energy demand savings of 12.28 %.

6. Conflict of Interest

This work is a partial analysis of the first author's master's thesis. The work is exclusively stated to be entirely written by the author. The author conducted experiments that produced the data that is described in this publication.

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