SEUJA,VOL. 3, NO. 2, DECEMBER. 2023, PP. 21-30

Southeast University Journal of Architecture

Journal homepage: www.seu.edu.bd/seuja

Evaluating the Performance and Sustainability of Glass Facade Materials for Office Buildings: A Comparative Analysis of Single and Double-Glazed Glass in Bangladesh

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ARTICLE INFORMATION

Received: November 16, 2023
Revised: January 10, 2024
Accepted: January 31, 2024
Published online: March 20, 2024

Keywords:
Office building façade,
energy efficiency,
appropriate choice of glass,
double glazing window,
cost-effectiveness

ABSTRACT

Rapid urbanization and rising demand for energy-efficient structures have forced the construction industry to investigate sustainable materials and design options in recent years. Modern office buildings are increasingly using glass facades because of their aesthetic appeal and potential for increased daylighting. In the context of office buildings in Bangladesh, this study gives a thorough evaluation of the performance and sustainability of two regularly used glass façade materials, namely single-glazed and double-glazed glass. Our research's findings emphasize the importance of glass façade materials in office buildings, especially in light of Bangladesh's tropical environment. This study shows the excellent qualities of double-glazed glass. and how double-glazing increases energy efficiency, improves thermal comfort, and generates significant long-term economic advantages. This study promotes the use of double-glazed glass as an affordable and sustainable alternative for office buildings in Bangladesh, providing better working conditions and enhancing the sustainability of built environments as a whole.

1. Introduction

Building designs that are ecological and energy-efficient are more important in today's architectural and construction sector. Given the urgent need to mitigate the negative impacts of excessive non-renewable energy use, the necessity for radical initiatives in a number of disciplines is more apparent than ever (Khan, Han, Khan, & Oanh, 2021). The construction industry, which is entrusted with lowering its energy footprint and incorporating sustainable building practices, is crucial to this paradigm change (Kumar et al.,2018). Windows are important part of our project since they are crucial to the layout of buildings and have a big influence on how cozy and energy-efficient they are as a whole.

Due to its ability to combine aesthetic appeal with the best possible exploitation of natural light, glass facades have become a popular architectural choice in the construction of modern office buildings (Menon, Kolhatkar, & Jadhav, 201). Nevertheless, depending on the unique climatic and environmental characteristics of a particular location, the careful selection of glass materials is a crucial factor. The sustainability and general effectiveness of buildings are greatly impacted by this choice.

The choice between single and double-glazed configurations deserves careful consideration in the context of glass facade materials (Forughian & Aiini, 2017). Single-glazed glass is frequently used because it is straightforward and affordable, although it has built-in thermal insulation limits. In contrast, because double-glazed glass has an extra insulating layer, it may provide greater energy efficiency. However, a prudent evaluation becomes necessary, taking into account the short- and long-term costs connected with the use of double-glazed glass systems.

By conducting a thorough investigation into single and double-glazed glass facades within the context of office buildings, this study aims to fill this important information gap. The study framework is purposefully placed inside

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This article is published with open access at www.seu.edu.bd/seuja
ISSN No.: 2789-2999 (Print), ISSN No.: 2789-3006 (Online)

Bangladesh's unique climatic milieu, a country distinguished by tropical weather conditions replete with significant humidity and noticeable temperature swings. Bangladesh has experienced an exceptional rise in energy consumption as a result of the effort to design energy-efficient office buildings, which is being pushed by the pressures of a growing economy and rapid urbanization (Joarder, Weir, Barckhausen, Stahr, & Fadeeva, 2022). As a result, it is essential to implement green construction practices in a serious manner as a tactical reaction to the arising environmental imperatives.

Here, the prime objective of this study is to assess the aesthetic comfort and daylighting possibilities of single- and double-glazed glass facades in Bangladeshi office buildings as well as their thermal performance. The amount of cooling and heating needed is calculated, energy consumption patterns are examined, and the initial and long-term costs of using these materials are calculated. Finally, the best glass façade material for sustainability and energy efficiency is also suggested.

2. Literature Review

Glass facades have become increasingly popular in modern office building construction due to their aesthetic appeal, potential for enhanced daylighting, and contribution to a more open and visually appealing workspace. However, the performance and sustainability of such structures ultimately depend on the choice of the right glass materials. The performance and sustainability of glass façade materials, especially single and double-glazed glass, in the context of office buildings in Bangladesh are the main topics of this literature review.

When beginning a project that is climate-compatible, it is crucial to use techniques and approach software, paying attention to the local environment and climate-compatible materials to produce greater setup (Tommerup & Svendsen, 2005). The requirement to offer a mechanism to calculate the energy savings was addressed by (Krarti et al., 2005). Additionally, he examined four building geometries with various coverings and indicated how closely windows and their frames relate to energy savings (Krarti et al., 2005). In addition to the approaches already described, software tools may be used to study the efficacy of windows and canopies in terms of kind, material, number of chambers, orientation, and other parameters.

The impact of windows on occupants' thermal comfort (Hom.B.Rijal, et al., 2007), energy consumption by allowing daylight into living or working spaces, which helps to reduce energy consumption by 50–80% (Bodart & Herde, 2002), and finally the effect of chamber number on reducing energy consumption in buildings have all been thoroughly reviewed. In a study, several glass types, their walls, and the various types of air used between the walls were all examined. The study's windows included single-glazed, triple-glazed with 13 mm of Oregon, double-glazed with light-control coating, and double-glazed with 13 mm of air.

In another study, eight different types of double-glazed windows were compared. These included windows that were 6 mm clear on both sides and filled with 12 mm air, windows that were 6 mm clear on one side and coated with a light controller on the other side, and windows that were 6 mm blue on one side and transparent on the other side (Yasar & Kalfa, 2012).

3. Comparison of windows with single and double glazing

To undertake this research, a detailed examination of the initiation, administrative procedures, and allocation processes is necessary. Due to the dearth of previously conducted research on architectural design in this setting, primary data must be heavily relied upon. In order to successfully complete the research, both primary and secondary sources will be used. The author conducted a site visit to a relevant construction site and based their criticisms on what they saw there. This method guarantees a thorough and objective evaluation of the architectural design processes under study. Key Informant Interviews will be conducted with the key officials who have good knowledge about the initiation of the project. Development Project Proposal and Feasibility Study report will be collected from secondary sources of Rural Development Academy, Bogura , CIWM , LGED to collect the initiation process of the administrative framework and also the allocation process. From all these survey data, recommendations would be placed.

3.1. Thermal Performance of Glass Facades:

Several studies have investigated the thermal performance of glass facade materials in various climates. In tropical regions like Bangladesh, where high temperatures and humidity prevail, the effectiveness of glass in preventing thermal transfer is of utmost importance. (Symoens, Coile, & Belis, 2021) performed a study on the thermal characteristics of different glass types, emphasizing double-glazed glass' advantages in lowering heat gain and preserving interior thermal comfort. Similar findings were reported by (Bangre, Surwade, & Kamal, 2023), who emphasized the potential energy savings with double-glazed glass, especially when combined with low-emissivity coatings.

3.2. Daylight potential and visual comfort:

Due to its positive effects on occupant well-being, productivity, and energy efficiency, daylighting is a crucial component of office building design. (Hee, et al., 2015) investigated the daylighting performance of different glazing materials and reported that double-glazed glass provided better daylight penetration and distribution compared to single-glazed glass. Furthermore, Nabil and

Mardaljevic (2016) explored the correlation between glazing materials and visual comfort, affirming that double-glazed glass with low solar heat gain coefficient (SHGC) offered improved occupant satisfaction and reduced glare.

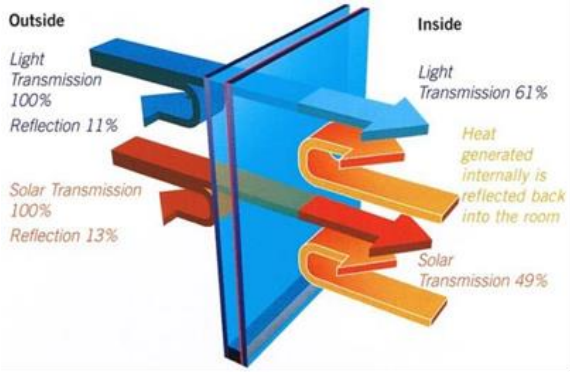


Figure 1. Functioning of 4 mm solar neutral tough and 4 mm elite tough Source: (21) (2017)

3.3. Energy Consumption and Environmental Impacts:

The energy consumption of office buildings is a key concern, particularly in countries like Bangladesh, where fossil fuel dependency is high. Life cycle assessment (LCA) studies have been instrumental in evaluating the environmental impacts of glass facade materials. Asif et al. (2019) conducted an LCA of single and double-glazed glass systems, considering their production, transportation, installation, and end-of-life phases. They found that double-glazed glass had a lower environmental impact, attributed to its superior thermal insulation properties and longer lifespan.

Single-glazed windows have a single pane of glass, providing minimal insulation, making them less effective in preventing heat loss or gain. They allow more heat to escape during winter and enter during summer, leading to higher energy consumption for heating and cooling. With the use of two panes of glass and an insulating barrier, double-glazed windows maintain consistent inside temperatures, lessen the need for excessive heating or cooling, and consume less energy overall.

3.4. Economic Considerations:

The economic viability of adopting energy-efficient glass facade materials is vital for decision-makers in the construction industry.

Single-glazed windows are generally cheaper than double-glazed windows in terms of initial cost, but their lower energy efficiency may result in higher long-term energy bills. Double-glazed windows, on the other hand, have superior energy efficiency, leading to significant long-term savings on energy bills and the potential for improved property value. In our tropical climate and corporate environment, double-glazed glass harmonizes comfort with cost-effectiveness according to (Kirankumar, et al., 2019).

Sound Insulation:

Single-glazed windows provide limited sound insulation, allowing outside noises to enter a building, particularly in noisy urban areas or near busy roads. Double-glazed windows, on the other hand, reduce condensation by creating an insulated air gap between glass panes, thereby maintaining a consistent temperature on the interior glass surface.

Energy conservation is double glazing's main goal. To calculate energy efficiency, a method known as the U Value is utilized. That example, it displays the quantity of thermal energy a window gains or losses, or how well a window (or another component of a structure) holds heat. The better, more energy-efficient, and more energy-saving device has a lower U value. A common U value for single glazing, for instance, may be 5.6. Depending on the properties of the glass used and whether argon gas or air is used to fill the space between the glass panes, the U value for double glazing can range from roughly 1.5 to 2.8. (Chowdhury & Paul, 2011) Employing building modeling software, a comparison of single- and double-glazed windows using thermal imaging. The kind and thickness of glass used has a significant impact on the energy efficiency of windows, whether they are double- or single-glazed.

Their study demonstrated that although double-glazed glass had a higher upfront cost, the long-term energy savings outweighed the initial expenditure, resulting in a favorable return on investment.

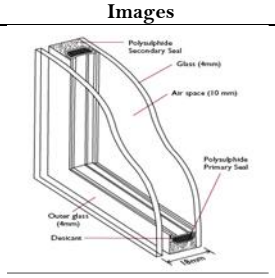
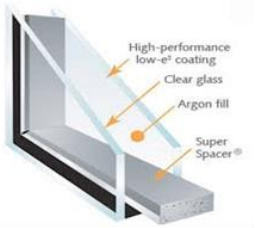
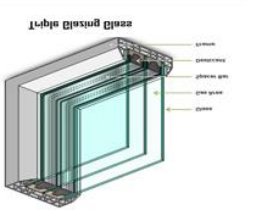
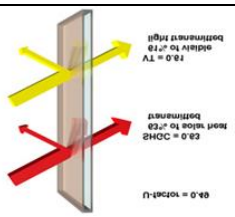
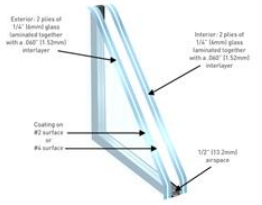
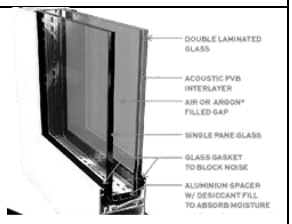
Table1. Characteristics & features of double-glazed glass

Characteristics of double-glazed glass	Description
Spacing	The usual distance between panes is between 12 and 16mm. For best thermal performance, a minimum spacing of 12mm is advised. Alternately, there are ways to permanently regulate the acoustics and reduce low-frequency noise, including recommending a minimum 150mm air gap between traffic and airplanes as the best distance. Be aware that such big gaps permit a reduction in convection between the window's insulating capabilities. Source: [22] (2023)
Light Transmittance	Insulating glazing systems generally have visual light transmittance between 7% and 80% and visible light reflectance between 13% and 48%. Source: [23] (2023)
Noise Reduction	By combining laminated glazing and inert gases, it is possible to further reduce noise by roughly 30 dB. Insulating glazing can also help. Source: [24] (2023)
Energy Efficiency	Low E insulating glazing can therefore be a net contributor to energy savings in Bangladesh.

4. Typologies of double-glazed glass

Double-glazed windows are designed to enhance energy efficiency, thermal insulation, and soundproofing by incorporating two glass panes with a sealed airspace between them. Various typologies of double-glazed windows are available, each offering unique benefits and features. Here are some common glass typologies of double-glazed windows:

Table 2. Typologies of double-glazed glass

Typology	Description	Images
Standard Double-Glazed Windows	Standard double-glazed windows have two glass panes that are sealed at the edges and spaced apart by a spacer bar. In order to increase insulation, the area between the glass panes is frequently filled with air or a low-conductivity gas like argon or krypton. Compared to single-glazed windows, these windows provide superior thermal performance and noise reduction.	
Low-E Double Glazed Windows	Low-emissivity (Low-E) double-glazed windows have a microscopically thin, transparent coating applied to one of the glass surfaces. This coating is designed to reflect heat into the room while allowing natural light to pass through. Low-E windows are very energy-efficient because they assist to manage inside temperatures, prevent heat loss in the winter, and minimize heat gain in the summer.	
Gas Filled Double Glazed Windows	Some manufacturers utilize low-conductivity gases like argon or krypton to fill the gap between the glass panes in addition to conventional double-glazed windows. These gas-filled double-glazed windows further enhance thermal insulation, reducing heat transfer and improving energy efficiency.	
Triple Glazed Windows	While not technically double-glazed, triple-glazed windows are worth mentioning as they are becoming increasingly popular for their superior thermal performance. Triple-glazed windows incorporate three glass panes separated by two insulating spaces, which significantly improves energy efficiency and sound insulation compared to standard double-glazed windows.	
Tinted Double-Glazed Windows	Tinted double-glazed windows have a colored or reflective film applied to the glass surface. The tinting helps to reduce glare, minimize solar heat gain, and provide additional privacy while maintaining good thermal performance.	
Laminated Double-Glazed Windows	Laminated double-glazed windows feature an interlayer between the glass panes, typically made of polyvinyl butyral (PVB). This interlayer enhances the window's structural integrity, making it more resistant to impact and breakage. Laminated glass also provides sound insulation benefits.	
Acoustic Laminated Double-Glazed Windows	Acoustic double-glazed windows are specifically designed to minimize noise transmission from the outside environment to the inside of the building. These windows feature thicker glass panes, different airspace widths, and acoustic insulation materials to enhance soundproofing.	

Source: [25] Standard Double Glazed;(2023); Low E Double Glazed Glass:(2023); Gas Filled Double Glazed Glass:(2023); Triple Glazed Window:(2023); Tinted Double Glazed(2023); Laminated Double Glazed:(2023); Accoustic Laminated Double Glazed:(2023)

4.1. Selection of double-glazed window typology:

Low-e double-glazed windows offer a wide range of

advantages over other varieties of double-glazed windows, such as those without low-e coatings or with less sophisticated coatings, that prioritize energy efficiency, comfort, and defense against dangerous UV radiation. (Somasundaram, Thangavelu, & Chong, 2020) As a result, they are a popular option for homeowners and in the case of office spaces hoping to get the most out of double-glazing technology.

These are the characteristics of Low-E double-glazed glass that make it preferable:

Table 3. Characteristics & features of Low-E double-glazed windows

Characteristics of Low-E double-glazed windows	Description
Better Thermal Performance	Low-e coatings effectively reflect heat radiation, enhancing window insulation and indoor temperature control. They block visible light, allowing natural light to illuminate interiors while preventing heat from the sun's rays, which contain infrared radiation, from entering homes during hot seasons. This selective heat control method lowers the demand for heating and cooling systems, thereby reducing the need for heating and cooling systems.
UV Protection	Low-e coatings can significantly reduce the amount of harmful ultraviolet (UV) light that can fade and ruin carpets, furniture, and other interior decor. This safeguard assists in preserving
Noise Control	Low-e double-glazed windows can reduce noise to some extent, despite not being their major function, thanks to the extra glass layer and insulation they give. This may result in a quieter atmosphere inside.
Value in the Long Run	Low-e double-glazed windows are a long-term investment that will pay off in the form of decreased energy costs, a rise in home value, and improved comfort. Their ability to conserve energy can result in significant long-term savings that offset the original investment. (Nedhal & Qahtan, 2016)

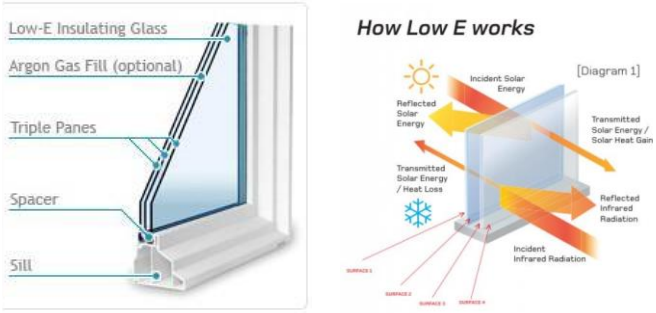


Figure 2. Double-glazed Low-E glass section and its workability Source: (Naser, Haghparast, Singery, & Sarbangholi, 2021)

5. Methodology

The major objective was to compare the results of employing single-glazed and double-glazed glass to discover how they varied from one another in terms of cost efficiency. For this reason, we chose an office floor a building with double-glazed glass façade and ran simulation to see the energy efficiency of this material and how much difference it would make if the office floor had single-glazed glass façade. The procedure of the method we followed is given below:

a. **Survey:** The place of study was an office floor, situated at level 3 of Square Food & Beverage Ltd building, Banani, Dhaka. We collected necessary data on the office floor like electrical equipment and their numbers, HVAC system used within the office, floor dimensions, material used in the façade, floor and ceiling, office hours, etc.

b. Building Model creation: Creating a comprehensive 3D model of the office floor using Design Builder, including precise representations of the walls, windows, doors, and other architectural elements. Make sure the building model is a true representation of the actual office floor and that it is spatially precise.

c. Glazing Properties: Specify the differences between single- and double-glazed glass as glazing materials. Assign each glazing type the appropriate U-value (thermal transmittance), Solar Heat Gain Coefficient (SHGC), and Visible Light Transmittance (VLT) values based on the information at hand or the manufacturer's requirements. Check to see if the glazing features truly match the performance traits of the chosen glass kinds.

Table 4. Window glazing data table

Simple Glazing System Descriptor	Operating Type	Frame Material	Glazing Type	Outer Glass Type	U-Value	SHG C	VLT	Vision%
Single glazed, clear	Hinged/ Projected	Aluminum	Single glazing	clear	6.7	0.57	0.54	0.59%
Single glazed, tint	Hinged/ Projected	Aluminum	Single glazing	tint	6.6	0.41	0.46	0.63%
Single glazed, clear	Fixed/ Sliding	Aluminum	Single glazing	clear	6.7	0.70	0.68	0.76%
Double-glazed, tint / clear, air-fill	Fixed/ Sliding	Aluminum	Double-glazing with air fill	tint	5.2	0.39	0.49	0.73%
Double-glazed, tint / clear, Argon fill	Fixed/ Sliding	Aluminum	Double-glazing with Argon fill	tint	5.1	0.36	0.46	0.72%
Single glazed, clear	Hinged/ Projected	Timber / uPVC / Fiberglass	Single glazing	clear	5.4	0.56	0.55	0.61%
Single glazed, clear	Hinged/ Projected	Composite	Single glazing	clear	5.9	0.57	0.55	0.61%

d. Weather Data: Access location-specific weather data for the office floor's geographical area. Import the weather data into Design Builder to ensure that the simulations are based on the actual climate conditions of the site. Weather data for Bangladesh was taken from: Source [28] (2023)

e. HVAC System: In the Design-Builder, create a sample HVAC system setup for the office floor. Set the equipment, controls, setpoints, and operational schedules for the HVAC system by reasonable hypotheses and usual usage patterns.

f. Simulation settings: Configure the simulation settings, including internal gains, equipment loads, lighting use, and occupancy schedules. Enter correct occupancy and activity data for the building to reflect how it will be used throughout the simulation period.

g. Energy Simulation: Run energy simulations in Design Builder for both the single-glazed and double-glazed glass variants of the office floor. Ensure that the simulation time step and convergence criteria are appropriately defined to achieve reliable results.

h. Data Collection and Analysis: Collect the simulation results, including the electricity consumption data, from the Design Builder's output files. Compare the energy consumption values between the single-glazed and double-glazed glass scenarios.

i. Cost Savings Analysis: Calculate the cost savings gained by employing double-glazed glass as opposed to single-glazed glass. Include the local power cost per unit (kWh) to get the overall cost savings for the full office floor over a certain period.

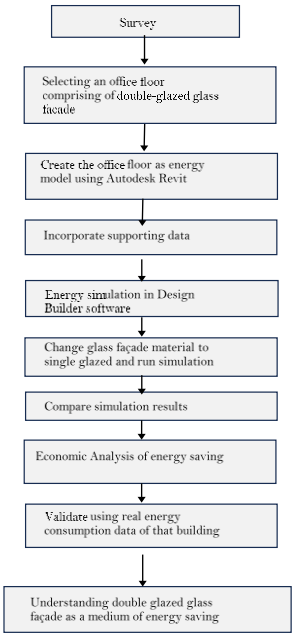


Figure 3. Methodology chart

6. Result and discussion

6.1. Review Model

Calculations were performed on a real-world sample building keeping in mind the study's objective, which was to assess the impact of windows on energy exchange.

Figure 4. Square Food and Beverage Ltd building. Location: 11/C, Road No-27, Banani, Dhaka. Source: Author

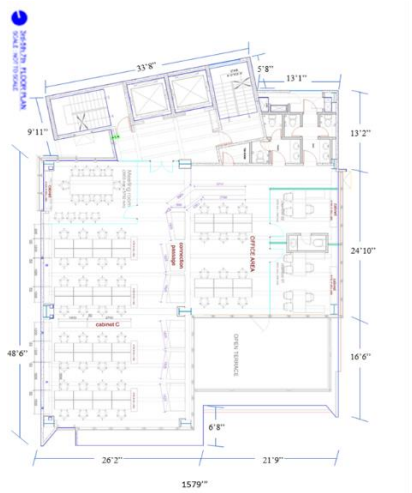


Figure 5. Floor plan of level-3 office floor of Square Food and Beverage

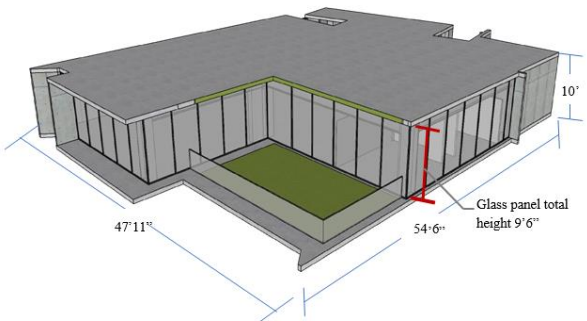


Figure 6. 3D Model of level-3 office floor of Square Food and Beverage Ltd building. Source: Author

6.2. Simulations through software

The factors that affect energy consumption in buildings the most are the geometry and design of various components, the climatic conditions, and this will be made possible by a thorough investigation of the site. One of the most important architectural features, windows, is essential to energy conservation in terms of both the heating and cooling load and the design, which may reduce energy loss by capturing more solar light. Windows also play a vital role in the design of buildings. Depending on the size and orientation of the windows, various behaviors are taken into consideration.

With the primary objective of this study in mind, different mathematical formulas were chosen and analyzed to quantify the quantity and kind of savings and arrive at savings estimates; among these, Design Builder software was chosen as the most suitable program. Windows were calculated and simulated using Design Builder. Graphs were used to present the findings.

Information on the windows in the single- and double-glazed examples is shown in (Figures 7 & 8), respectively. The sole change in the construction was the type of windows, which is discussed in this research together with the materials of the walls and ceiling (Figure 9).

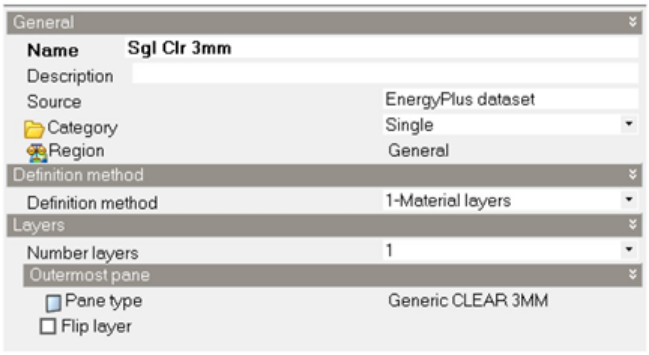
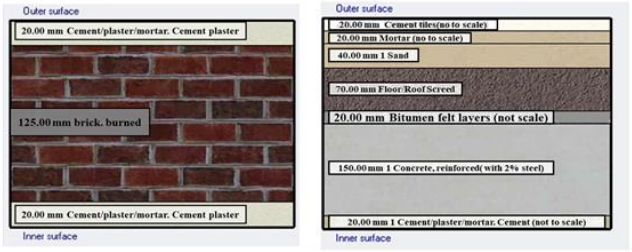


Figure 7. Single glazed

Figure 8. Double glazed



(a) (b)

Figure 9. Section of (a) wall and (b) ceiling.

The altitude (elevation) and azimuth (side) angle of the sun are typically specified for each location. The altitude angle of the sun is its angular height in the sky as seen from the horizontal. The azimuth angle is the angle that a horizontal projection of a direct solar beam makes with the real north-south axis. The latitude of the site affects both annual and daily variations in the angle (Table 5).

Table 5. Climate data table

Average sunlight in Bangladesh	**3.8-6.42 kW-hr/m²**
Total monthly sunny hours (March)	256 hours
Monthly rain- precipitation rate	2.5 mm-7.6 mm
Minimum relative humidity (avg)	57%
Maximum relative humidity (avg)	83%
Relative humidity (avg)	45%-79%
Daily temperature average	24° -32°
Maximum daily temperature	32°
Minimum daily Temperature	10°

Source: Bangladesh Meteorology Department

Due to the comparatively moderate temperature, natural gas is not typically used to heat buildings in Bangladesh. But in the case of office buildings, gas might be used to some extent for equipment. In Tables 3 and 4, we look at the average monthly costs for electricity and gas use while using single-glazed glass. In Tables 5 and 6, we look at the same data using double-glazed glass. In Dhaka, Bangladesh, the electricity price for commercial purposes is 8.99 BDT per kWh. Source: [29] (2023)

6.3. Result Data

Table 6. Average electricity loads each month for single-glazed glass

Month	Average electricity load (kWh)			Total	Total cost in BDT
	Cooling	Lighting	Equipment		
January	0	496	498	994	8936.06
February	224	520	537	1281	11516.19
March	589	500	522	1611	14482.89
April	600	480	498	1578	14186.22
May	682	512	520	1714	15408.86
June	690	495	500	1685	15148.15
July	638	527	535	1700	15283
August	600	515	515	1630	14653.7
September	623	497	510	1630	14653.7
October	598	508	500	1606	14437.94
November	324	485	520	1329	11947.71
December	0	498	535	1033	9286.67

Source: Author

Table 7. Average electricity loads each month for double-glazed glass

Month	Average electricity load (kWh)			Total	Total cost in BDT
	Cooling	Lighting	Equipment		
January	0	398	398	796	7156.04
February	200	405	427	1032	9277.68
March	498	390	422	1310	11776.9
April	506	415	398	1319	11857.81
May	512	398	420	1337	12019.63
June	527	425	400	1352	12154.48
July	539	408	399	1346	12100.54
August	510	385	421	1316	11830.84
September	495	402	410	1307	11749.93
October	498	418	405	1321	11875.79
November	225	425	420	1070	9619.3
December	0	393	415	808	7263.92

Source: Author

(Figure 10) compares how much power is used by windows with single and double glazing. Later, total annual cost comparison of electricity load for both the cases are shown in (Figure 11) both single- and double-glazed window.

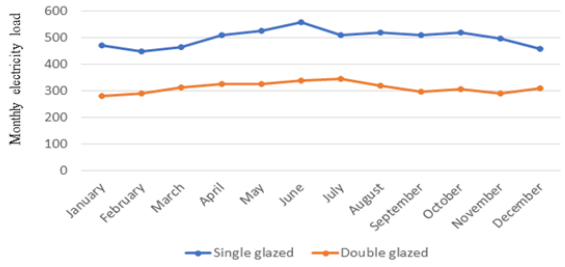


Figure 10. Month-wise electricity load

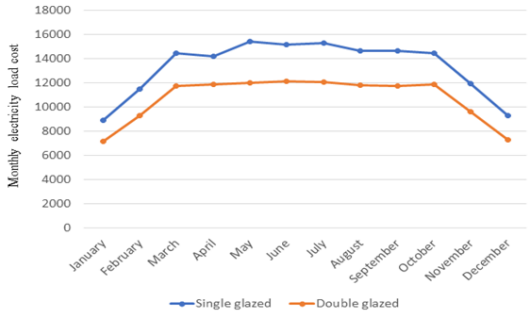


Figure 11. Month-wise cost of electricity load

6.4. Discussion

The increased energy efficiency of double-glazed windows offsets their higher initial cost with considerable long-term energy bill reductions. In the long run, double-glazed windows are a cost-effective investment due to the decreased energy usage and potential for increased home value.

The data gathered through Design Builder shows a difference between usage and consumption, which results in a considerable drop in both energy consumption and financial value.

The information in Table 6 illustrates the average consumption rate and cost if single-glazed glass is used. The average electrical load per month is 16161 kWh which costs around 159941.09 tk. Table 7 demonstrates the same for double-glazed glass, where the average monthly electricity load consumption reduces to 14314 kWh for 128682.86 tk. The difference between the total cost is 31258.23 tk annually for electricity load consumption.

(Fig. 10), which compares the amounts of electrical load in single- and double-glazed windows. The entire yearly cost comparison for electrical load for both scenarios is illustrated in the following (Fig. 11), which compares costs

for windows with single and double glazing. Month-wise electricity load comparison shows the drastic difference between single-glazed and double-glass costing around 75% which supports the fact that double-glazed glass is beneficial in the long run.

The findings of this study underscore the significance of choosing the right glazing options for office buildings. When it comes to cost savings, energy efficiency, and occupant comfort, double-glazed glass performs better than single-glazed glass. Double-glazed windows have a larger upfront cost, but the long-term advantages vastly outweigh that. The benefits of double-glazed glass should be considered holistically, taking into consideration lower operating costs and improved interior air quality, by building owners and designers.

7. Conclusion

The study provided a thorough analysis of the effectiveness and sustainability of glass facade materials for office buildings in Bangladesh's tropical environment providing significant information for architects, engineers, and stakeholders in the construction industry to make educated decisions about energy-efficient and ecologically responsible building practices through a comparison of single and double-glazed glass.

The advantages of double-glazed glass over single-glazed glass in terms of energy efficiency, thermal comfort, and long-term cost effectiveness have been especially noted. Double glazing is a wise solution for business settings where comfort and energy efficiency are vital and may enhance working conditions and result in long-term savings outperforming single-glazed glass in several ways.

The knowledge acquired from this study helps Bangladesh's continuous attempts to develop environmentally conscious, energy-efficient, and aesthetically pleasing office buildings, paving the way for a more successful and sustainable future for the nation's environment. The results of this research serve as a compass for reshaping Bangladesh's skyline while protecting its natural resources and reducing the effects of climate change as the building sector adopts creative and sustainable solutions.

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