P-ISSN: 2709-6254	Journal of Development and Social Sciences	Apr-June 2024, Vol. 5, No.2
O-ISSN:2709-6262	https://doi.org/10.47205/jdss.2024(5-II)55	[586-593]

JDSS Journal of Development and Social Sciences
www.jdss.org.pk

RESEARCH PAPER

Stimulation-Based Comparative Analysis of Single-Glazed and Double-Glazed Windows in Residential Unit, Lahore Pakistan

[1]Ar. Maryam Jamil * and [2]Dr. Malik Usman Awan

1. Lecturer, Architecture Department, Lahore College For Women University, Lahore, Punjab, Pakistan
2. Assistant Professor, Architecture Department, University of Engineering & Technology, Lahore, Punjab, Pakistan

***Corresponding Author:** marymajmail369@gmail.com

ABSTRACT

The objective of the study is to calculate the thermal response of different types of glazing windows used in buildings to achieve a sustainable environment. However, buildings experience a significant amount of heat gain or loss through and this will affect the thermal comfort of the building's occupants. One of the essential parts of the window is the glazing. Selecting a window glazing is complicated when energy saving and day lighting aspects of a building are considered concurrently. The study involves the estimation of changes in the numerical values regarding the heating and cooling load of a residential unit in the case of replacing glazing from a double-glazed with a single-glazed window. A model of a single-story residential structure prototype has been taken as a case study in the climate of Lahore. The calculation has been compared with values of direct solar gains, heat gains, and losses throughout the year. A quantitative research-based approach has been used. Overall, the results indicate that during summers the Double-glazed window units have 37% less heat gain and during winters 36% less heat loss as compared to Single-glazed window units. Thus, double-glazed windows are more effective in terms of energy efficiency in comparison to single-glazed windows.

KEYWORDS Building Systems, Glazing, Energy Performance, Residential Buildings, Window

Introduction

Different aspects that have direct impact on the Energy consumption of buildings are site climatic conditions, building geometry/orientation, and various building components that need to be carefully analysed before execution. Among them, windows are one of the most important elements that had huge impact in saving energy, both in terms of either cooling or heating depending upon climatic conditions. For this purpose, different energy simulation software were used at the design stage to calculate heating and cooling loads to improve building energy efficiency.

The purpose of building construction is to accommodate human activities that need comfort both in terms of visual and thermal. The objective of this is to get occupants a contented environment that will be achieved by involving all aspects of comfort in the interior environment throughout the year, at every time (Hunn, 1996).

Moreover, windows are considered to be significant for both physical and psychological reasons that are directly associated to the environment. It is possible to achieve lower heating and cooling levels by having a good glazing design and achieving reduced energy outputs. (Menzies & Wherrett, 2005)

Buildings are responsible of consuming 30 -40% of the energy in the world and are responsible for more than 1/3 of greenhouse gas emissions. In Pakistan, only the residential sector consumes 47% of total energy. As more and more energy is consumed it's leading to greenhouse gas emissions which ultimately cause global warming. As the population of the world is increasing rapidly the requirement for residential units is also increasing which ultimately results in increased demand for energy. Recent reports on climate change by the international panel have tried to raise public awareness about energy usage and its environmental implications. With the prevailing weather conditions due to climate change, one must understand the relationship of energy consumption in present era.

47 % of energy is consumed by residential units in Pakistan which is a lot of amount. The gap between the energy consumed and generated is increasing in Pakistan to a great extent. For instance, Lahore is the major city of Pakistan. The city has 81% of cemented houses plastered from both inside and outside. The main energy supply is electricity, natural gas, and CNG. Where only 56% of houses have a supply of electricity to provide a better place to live n. In Pakistan, the climate is mostly temperate where more heating is required for cooling in buildings.

As compared to the international average in Pakistan, the amount of energy consumption by the building sector is much higher. To reduce this demand external fabric of facades should be designed by using energy-efficient building materials and according to the Green Building Energy Code. We can minimize the energy demand of the building sector by using sustainable modern materials. The energy consumption in the buildings can be minimized by using double glazing and low-E (low emissivity) at external and internal fabric. Furthermore, the size and orientation also help in an annual decrease of energy consumption (Bokel 2007).

Literature Review

Different types of glazing will be analysed in the basis of their energy efficiency for different climatic regions like hot humid, temperate, hot dry and cold climates. The window is one of the most essential parts of a building that directly affects heat gain and heat loss. The most important factor is the orientation of the building and most importantly is in which orientation it is placed and what techniques have been adopted to decrease heat loss and gain considering the provision of daylight. (Sullivan & Selkowitz, 1985)

The response factor (thermal resistance of Double-glazed windows having glass panes of two or three sandwiched with a layer of insulation (air or inert gas) between each pane, than single-pane windows. (Rousseau, 1988). The fact is that layer r of air acts as insulation, delaying the time of heat exchange and preventing heat gain and losses.

While considering all of the physical effects (i-e thermal, energy, acoustic, light penetration, and fire protection), it is realized that the facades with double glazing are not mostly suitable for Northern Europeans in some special cases. It clearly specifies that it is possible to reduce the risk of high temperatures or energy needed for cooling, and the ideal size of window south facing that is smaller.

A study explored the suitability of glass double-glazing in comparison to glass single-glazing façades in reference to energy efficiency and found that double-skin glass facades are about 22.84% more efficient in term of heat gain and loss as compared single-glaze in climate of Istanbul (Ozkan 2005).

Another research was conducted that calculates the thermal ideal thickness for insulation layer between the panes of two glass for diverse climates. By keeping temperature and convection, two difference fabric details were applied on surface and analyzed. The results shows considerable reduce in energy losses through double pane by adjusting air layer thickness (Orhan 2006).

The effect of use of different glazing on energy demand has been studied and results found out that switchable glazing application would give reduction of upto 6.6% on annual electricity cost, remaining factors of building typology, orientation were apart (Francis, & Milorad, 2005)

Another study investigated that, estimates the reduce in energy demand can be attained by the application of advanced glazing for a specific high-rise building structure. The results shows a reduction in electricity cost by upto 4.2% with the application of low e-glazing. (Francis, & Milorad, 2007)

Material and Methods

The methodology of this study involves a quantitative-based approach and has 4 steps involved. Firstly, the base model of a single-storey unit has been modelled on software. The provision of windows on almost all the orientations North, South East, and West were given to study the stimulation-based thermal analysis of the unit in the climate of Lahore. The model remain the same with all specification of materials of walls, roof, and flooring with alteration based on single and double glazing.

Finally, the analysis was accomplished based on the stimulation parameters of the software's and model limitations were calculated based on conventional materials and construction technique.

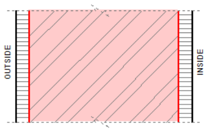
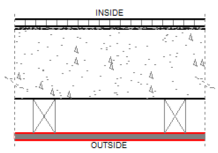
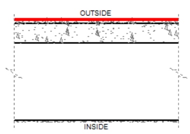
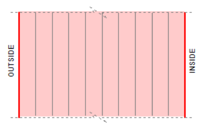
Description Base Model / Climate Data

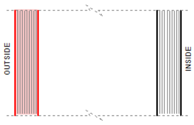
A simple single-storey structure having windows on almost all four sides North, South East, and West was developed to study the stimulation-based thermal analysis of the unit in a climate of Lahore. The model remain the same with all specification of materials of walls, roof, and flooring with alteration based on single and double glazing.

Lahore had a semi-arid climate as described by Koppen Climate Classification. The city record high temperature was 50.4 ∘ C

A prototype structure of a single residential unit has been developed using conventional materials available. Computer simulation techniques act as a very helpful tool to analyse the thermal performance of projects in future.

Table 01
Materials Specifications Used In Base Model for Stimulation Analysis

SR.#	ELEMENT	CONSTRUCTION DETAIL	SPECIFICATIONS	LAYERS
	Walls	9 " brick with 0.5" plaster either side	U value W/m^2 K= 2.620 Solar Absorption=0.418 Admittance W/m^2 K= 4.380 Thermal Decrement=0.7	
	Flooring	3 " thick suspended concrete floor plus ceramic tiles.	U value W/m^2 K= 2.9 Solar Absorption=0.475 Admittance W/m^2 K= 5.210 Thermal Decrement=0.69	
	Roof	Suspended concrete ceiling with ½ " tile & 6 "concrete slab	U value W/m^2 K= 2.560 Solar Absorption=0.326 Admittance W/m^2 K= 4.20 Thermal Decrement=0.7 Visible transmittance=0	
	Windows	Single Glazed glass with Aluminium frame Width= 5 mm Specific heat= 836.800 Conductance= 1.046	U value W/m^2 K= 6.000 Visible transmittance=0.753 Admittance W/m^2 K= 6.000 Refractive index=1.74 Heat Gain Coefficient=0.94	

Windows	Double Glazed glass with Aluminium frame Glass Standard (layer 01): Width= 5mm Specific heat= 836.800 Conductance= 1.046 Air gap (layer 02): Width= 0' 1" Specific heat= 1004.0 Conductance= 5.560 Glass Standard (layer 03): Width= 5mm Specific heat= 836.800 Conductance= 1.046	U value W/m² K= 2.260 Visible transmittance=0.639 Admittance W/m² K= 2.2 Refractive index=1.74 Heat Gain Coefficient=0.75	

Results and Discussions

In terms of energy consumption & thermal comfort, the most important factor is glazing types that significantly affect the building's thermal performance, heating and cooling. Based on the Glazing type the energy performances have been calculated on majorly four major times of year that is the summer solstice (21st June), the winter solstice (22nd Dec), and spring and autumn equinox (23rd March & 23rd April). The results for each configuration were compared taking into account different windows glazing types.

Table 02
Temperature Profiles Comparison

Date	Single Glazed	Double Glazed	Difference
June, 21	Avg. Temperature: 37.2 C Total South Window: (5.4% flr area). Total Window Area: 13.873 m² (30.5% flr area). Total Conductance (AU): 152 W/°K Total Admittance (AY): 1323 W/°K **Thermal Response Factor: 7.87**	Avg. Temperature: 36.2 C Total South Window (5.4% flr area). Total Window Area: 13.873 m² (30.5% flr area). Total Conductance (AU): 243 W/°K Total Admittance (AY): 907 W/°K **Thermal Response Factor: 3.54**	Difference in response factor: **4.33 (55%)**

Thermal response aspects of building envelopes are vital evidence in the design of thermal systems. The calculations shows that Thermal response factor for single glazed window unit is 7.87 and for double glazed window unit is 3.54. It means that double glazing has two times more capacity to reduce heat gain in the building strcuture during summer season and prevent heat loss from the structure during winter season.

Table 03
Hourly Gains/ Losses

Zone: All Visible Thermal Zones				
Date	**Single Glazed**	**Double Glazed**	**Difference**	**Result**
June, 21	Total Gain: 16317 watts = 16.317 KW	Total Gain: 10279 watts = 10.279 KW	**37 %**	Double glaze has 37% less heat gain as compare to Single glaze
Mar, 23	Total Gain: -8736 watts = -8.736 KW	Total Gain: -5963 watts = -5.963 KW	**31 %**	Double glaze has 31% less heat loss as compare to Single glaze

Sept, 23	Total Gain: 7688 watts = 7.688 KW	Total Gain: 5502 watts = 5.502 KW	**28 %**	Double glaze has 28% less heat gain as compare to Single glaze
Dec, 22	Total Gain: -75450watts = -75.45 KW	Total Gain: -48270 watts = -48.27 KW	**36 %**	Double glaze has 36% less heat loss as compare to Single glaze

Calculation of heat gain and losses throughout the year during different dates of year has been analysed and it found out to be that Double glaze has 37% less heat gain as compare to Single glaze during summer (21^{st} June) and 28% less heat gain on 23^{rd} Sep. Double glaze has 36% less heat loss as compare to Single glaze during winter (22^{nd} Dec) and 31% less heat loss on 23^{rd} March.

Table: 04
Direct Solar Gains

Months	**Single Glazed** Avg Value (Wh)	**Double Glazed** Avg Value (Wh)	**Difference**
JAN	542	225	58%
FEB	441	246	44%
MAR	395	250	36%
APR	434	256	41%
MAY	324	241	25%
JUN	342	265	27%
JULY	417	287	31%
AUG	478	292	37%
SEP	470	280	40%
OCT	422	270	36%
NOV	427	248	41%
DEC	454	231	44%

The results show that windows with double glazing show less values for direct solar gains as compare to single glazed windows especially for hot and humid climate double glazed windows are more effective in those months when temperature is high.

Table: 05
Passive Gains Breakdown

Single Glazed	**Double Glazed**
GAINS BREAKDOWN - Zone 1 FROM: 1st January to 31st December CATEGORY ------------ LOSSES ------- GAINS ------ FABRIC 26.6% 42.1%	GAINS BREAKDOWN - Zone 1 FROM: 1st January to 31st December CATEGORY ------------ LOSSES ------- GAINS ------ FABRIC 11.8% 25.5%

The results show that windows with double glazing in case of fabric show 11.8 % loss and 25.5 % gains while in comparison to Single glazed windows the values are 26.6% loss and 42.1 % gains with the difference in Loss is 14.8 % and in gains is 16.6 %.

Conclusions

Overall, the results indicate that during summers the Double-glazed window units have 37% less heat gain and during winters 36% less heat loss as compared to Single-glazed window units. Thus, double-glazed windows are more effective in terms of energy efficiency in comparison to single-glazed windows.

Recommendations

Considering the present day impact of climate change and increase in consumption of energy demands we should have to consider energy saving strategies in our designs, double glazed windows had proved to be more effective then Single glazed windows in terms of passive gains (heat gains, and solar gains) and passive adaptability index.

References

Azimi Hosseini, A. (2011). Effect of educational building orientation on heating and cooling loads in different climates. *Journal of Environmental Science and Technology. 1(2),* 78-92.

Barjastehbaf, Y. B. & Rahimi Zadeh Holaq, A. (2012). Simulates the effect of double glass to reduce energy consumption of buildings in our climate. *Journal of Energy Conservation*. (61), 71-82.

Bodart, M. (2001). Global energy saving in offices building by the use of daylighting, Universite Catholique de Louvain. *Journal of conservation energy. (48),* 82-91.

Abdulsalam E., & Mehdi, M. (2010). A method for generation of typical meteorological year. *Journal of Energy Conversation Management 51,* 410–7.

Feuermann, D. & Novoplansky, A. (1997). Reversible low solar heat gain windows for energy savings, *Ben-Gurion University of the Negev Pub. 283.*

Florides, G. (2002). Measures used to lower building energy consumption and their cost effectiveness, *Journal of Brunel University,* Uxbridge Pub

Francis, Y. & Milorad, B. (2005). Applicationof switchable glazing to high-rise residential buildings in Hong Kong. *Journal of Energy Build 38,* 463–71.

Francis, Y. & Milorad, B. (2007). Application of advanced glazing to high-rise residential buildings in Hong Kong. *Journal of Build Environment 42(2),* 820–8.

Hassouneh, K. & Alshboul, A. (2010). Influence of windows on the energy balance of apartment buildings in Amman. *Journal of Building Performance Simulation.* (93), 567-574.

Hussain Zadeh, S.; Giat Yeganeh, R. & Lak, A. (2013). Review and simulate the effects of windows in energy efficiency in buildings. *Journal of Architectural Engineering.* 96, 345-349.

Krarti, M. P.; M. Erickson & T. C. Hillman (2005). A Simplified method to estimate energy savings of artificial lighting use from daylighting, *Journal of Building and Environment. 40*, 747-754.

Menzies, G. & Wherrett R. (2005). Windows in the workplace: examining issues of environmental sustainability and occupant comfort in the selection of multi-glazed windows, *Journal of Energy and Buildings 37:* 623–630

Milorad, B. (2006). Application of overhangsand side fins to high-rise residential buildings in Hong Kong. *Journal of Environment System 23(4),* 271–85.

Ozkan, E. (2005). An approach for the evaluation of energy and cost efficiency of glass facades. *Energy Build 37,* 673–84.

Qiyabkoloo, Z. (2010). Set the environmental conditions affecting data set separation. *Journal of Architectural Science* Review. 95: 85 – 93.

Rayment, R. & Morgan, K. (1985). Energy savings from secondary windows. *Journal of Asian Architecture and Building Engineering*. 115, 163-171.

Rijal, H. B. (2007). *Using results from field surveys to predict the effect of open windows on* *thermal comfort and energy use in buildings*, Oxford Brookes University

Saboor, S. & Ashok, B. (2015). Effects of air space thickness within the external walls on the dynamic thermal behavior of building envelopes for energy-efficient building construction. *Journal of Energy Procardia 79,* 766- 771.

Tommerup, H. & Svendsen, S. (2005). Energy savings in Danish residential building stock, Technical University of Denmark. *Journal of Architectural and Planning Research*. *94:* 603-611.

Weir, G. & Muneer,T.(1998). Energy and environmental impact analysis of double-glazed windows, *Journal of Energy Conversion and Management, 39*(3-4), 243-256.