Research Article

An Empirical Study of Thermal Transmittance through Windows with Interior Blinds

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Abstract

The main function of windows is to control the indoor climate along to provide appropriate ventilation i.e air circulation. The main objective is achieved by scheming the heat flow through the window from inside to outside in winter & from outside to inside in summer. Window solar gain has a strong sway on the building energy utilization and peak cooling load. Double glazed window are known to avert the entry of solar gain to inside the room. Shading systems such as Venetian blinds, louver shades, draperies etc. enhances the control of solar gain through windows. In this paper the thermal performance of a double-glazed window with adjacent commercially available blinds has been studied using LBNL research software WINDOWS 6.3 and the results so obtained are validated using a Guarded Heat Plate Apparatus. Despite the fact that this type of glazing system has already been studied for colder climatic conditions in the west, due to the unavailability of literature on local climatic conditions its use in tropical countries like India is very limited. A parametric study for climatic conditions of an Indian city, Chandigarh has been made to give an insight to the thermal performance of glazing systems with interior blinds. In this study the effect of different types of glazing systems i.e single and double glazed , pane to blind spacing (20mm and 40mm) and the climatic conditions of Chandigarh (Hot and Dry, Hot and Humid, Cold and Dry) on the Thermal transmittance (U-value) is studied.

Keywords: Heat Transfer, Glazing, U-value, R-value

Introduction

Solar gain is spitted into three parts as it come across the a glazing material. Some of it is transmitted, while some is reflected, and the rest is absorbed as shown in Figure. 1. These three components has a major role in the solar heat gain coefficient and thermal transmittance or U-value (W/m2 k) , and other energy performance characteristics of a glazing system, such as the inverse of heat flow, or resistance to heattransfer, is expressed as Thermal Resistance or simply R-value. The roll of venetian blinds is to control sun-light and heat transfer up-to some extent and these are used along with windows. Due to these shading the affect of natural convection and radiant heat transfer from the window will be reduced; therefore there will be a change in the heat transmission and solar heat gain, through window. Solar radiation engrossed by glazing layers will throw in the temperature driven heat transfer, whereas the solar radiation which are transmitted through the glazing system will have no effect on the temperature driven heat transfer. A part of absorbed solar radiation will be transmitted into the conditioned space and will be included in SHGC.

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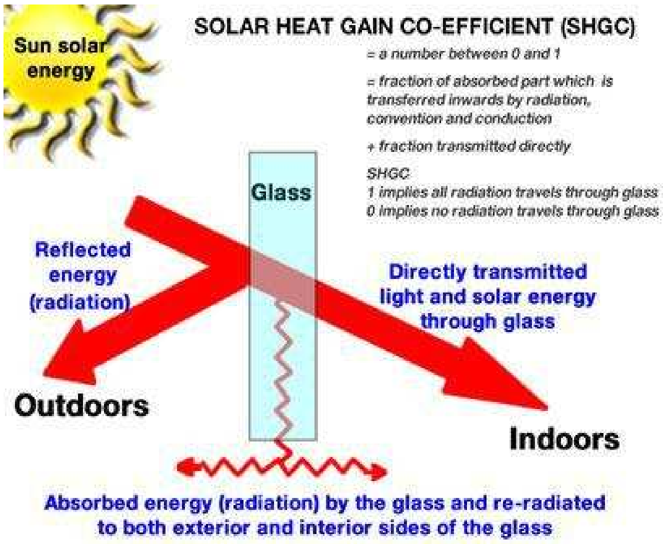

Figure 1.Three components solar heat

It is the law of nature that heat flows from warmer to cooler bodies, hence from inside to outside in winter, and vice-versa direction in summer, when the outside temperature is higher than indoors. The material used for making venetian blind is generally metal or plastic. Blinds made up of Wooden slats usually known as wood blinds or bamboo blinds. Venetian blind has horizontal or vertical slats, one above another. A number of studies have been done for these types of blinds in colder countries [2] [3] but still now their use in tropical countries like India is very limited. And even if these are used no weightage to thermal performance is given; only the aesthetic appeal is taken care of. This is due to the non-availability of research in this area. The author is of the view that a greater understanding of thermal performance of such system in Indian climate will give a greater impetus to their usage in tropical countries. India has six climatic zones [4]. All the northern states including Chandigarh fall in composite climate zone. Composite climate is further sub divided into three categories i.e Hot-Dry, Hot-Humid and Cold-Dry. The configuration selected for the present study consists of a double-glazed window with interior venetian blinds in Indian climate as shown in Figure 2.

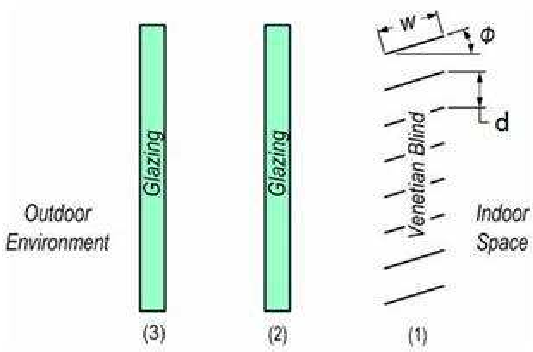

Figure 2.System layout: double-glazed window with indoor side venetian blind and blind dimensions [1]

Where w = width of blind,

ϕ = slat Angle,

d = distance between consecutive blinds

Software and Simulation

Software

The simulation is been done for the heat transfer through double-glazed windows with interior venetian blinds, the the simulating, Window 6.3 software, that is developed by the building technologies group at the Lawrence Berkeley Laboratory [5] and is freely available, LBNL WINDOW IBM PC compatible computer program. By using this software the calculation of the thermal and optical properties can be easily find out for heat transfer analyses of fenestration products. Any new products with the known thermal and optical properties can be easily added to the database of this software. The latest version of this software WINDOW 6.3 is released by the Lawrence Berkeley Laboratory. This version, give the freedom to change the most important parametric changes as well as the modelling geometrical models of different glazing systems. Some of the various parameters which can be changed are gap between different layers, types of blinds, slat angles, type of glazing, environmental conditions, fluid in between the panes. Hence by using different input parameters, results of various output conditions such as SHGC, U-value, Keff, (Effective thermal conductivity) etc. can be find out. All the calculations methods for finding out the various responses are readily available at LBNL website [6].

Simulation

One factor approach is used for the designing the simulated study, it also include the effect of control factors on response factor. For conducting simulation-runs for various glazing systems, the glass panes 635 x 635 x 3 mm size of are selected. And the slat angle is kept to be 0º. The Various levels of different input simulation factors are shown in table 1.

Table 1.levels of different input simulation factors

Levels	Control Parameters		
	Glazing Type	Pane- Blind Spacing (mm)	Climate
1	Single	20	Hot-Dry
2			Hot- Humid
3			Cold-Dry

The U-value of the single response$_2$ parameter$_{Double}$is considered$_{30}$. The full factorial approach consists of a design of total 12 experiments. The design along the response is shown in table 2.

Table 2.Full factorial design for evaluating U-value

S. No	Glazin g Type	Spacing (mm)	Climate	Experimental U-Value	Simulated U-Value
1	Single	20	H-D	4.18	5.12
2	Single	30	H-D	3.56	4.33
3	Double	20	H-D	2.23	2.72
4	Double	30	H-D	2.1	2.48
5	Single	20	H-H	3.72	4.54
6	Single	30	H-H	3.17	3.87
7	Double	20	H-H	2.13	2.52
8	Double	30	H-H	1.87	2.29
9	Single	20	C-D	3.85	4.7
10	Single	30	C-D	3.25	4.01
11	Double	20	C-D	1.98	2.41
12	Double	30	C-D	1.83	2.19

Where H-D = Hot-Dry Climate,
H-H = Hot-Humid Climate,
C-D = Cold-Dry Climate

The composite-climatic zone of India, is used for simulation heat transfer through the selected conFigureuration along with the input parameters having values corresponding to this climatic conditions. Form internet the averaged Wind-speed and solar radiation are obtained [7] to feed inputs to the software. Indian climate conditions are taken into consideration for designing the inner room temperature [8]. Through the software, for convectional heat transfer, ASHRAE/NFRC model and Windward Directional model are selected. Both the effective sky emissivity and the effective room emissivity are assumed to be equal to 1. The various properties of the air at standard temperature and pressure are shown in the table 3.Properties of air at standard temperature and pressure.

Table 3.Properties of air at standard temperature and pressure

Conduction Coefficient	Viscosity Coefficients	Specific Heat Coefficient	Density	Prandtl
KW/m k	Ns/m^2	KJ/kg C	kg/m^3	
0.0002405	0.0001785	1.0175	1.38848	0.7197

Table 4.Geometrical properties of Venetian Blind

Name	Material	Position	$Eff_{o.F}$	Slat width (mm)	Spacing (mm)	Thickness (mm)	Color
Venetian Blind	Al	Horizontal	0.05	16	11.988	0.635	Opaque Light- Dark

Table 5.Solar and optical properties of Venetian blind and glass

Description		Venetian Blind	Glass
Solar	Trans, Front (T_{sol})	0	0.83
	Trans, Back (T_{sol}^{2})	0	0.83
	Reflection Front (R_{sol})	0.7	0.08
	Reflection Back (R_{sol}^{2})	0.4	0.08
Visible	Trans, Front (Tvis)	0	0.9
	Trans, Back (T_{vis}^{2})	0	0.9
	Reflection Front (R_{vis})	0.7	0.08
	Reflection Back (R_{vis})	0.4	0.08
IR	Emis, Front (Emis1)	0.9	0.84
	Emis, Back (Emis2)	0.9	0.84

Experimental Set Up

The experimental set-up is shown in Figure.3. It is the similar apparatus that used by Wright and Sullivan, is used for the current investigation[9]. It is consists of primarily two copper plates one is hot copper plate whereas the other is cold copper plate, two water bath, circular copper tubes, temperature indicators of the bath, two rota-meter, heaters consist of a main and two guard heaters, glazing system, aluminum venetian blinds, 220 V power supply system and other accessories. The dimensions of the both copper plates i.e hot plate and cold plate are of the size 635x635x12.5 mm each. The plates are placed in such a manner so that they are facing each other and constant temperatures can be maintained. The constant temperatures of both plates is achieved by a circulating a steady flow mixture of water and glycol through a manifold of tubes attached at the back of the plates. There are three guarded heater plates in the hot copper plate. These heater plates are kept in the vertical position and at equal distance. The rate of heat transfer that is taking place over the face of each of the guarded heater can be measured. The electrical power supplied to the heater plate is adjusted till zero temperature difference is achieved between the heater plate and the warm copper plate. In this condition, there will be no heat transfer between the heater and the warm copper plate and all the electrical energy supplied is transferred across the gap to the cold copper plate. A heat flux meter is sandwiched between these two plates to sense the temperature difference. The glazing system to be tested is placed at the required position in between the plates.

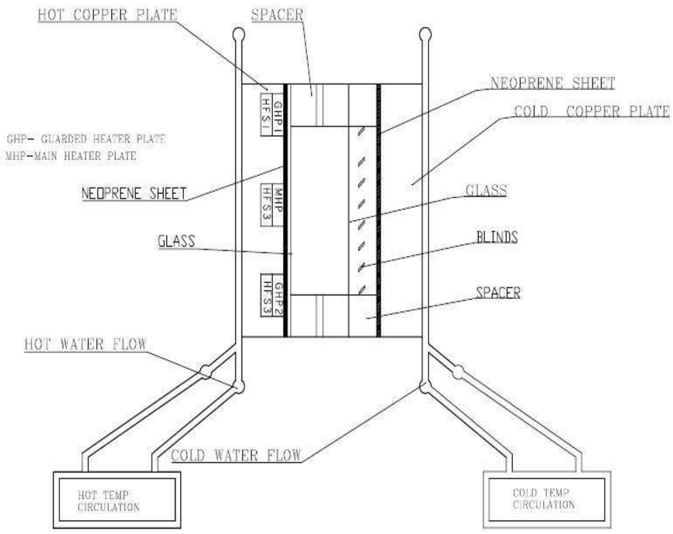

Figure 3.Schematic of experiment set up

In order to prevent the direct contact between the glazing system and the copper plates, A neoprene 3mm thick sheet is placed between the glazing system and the copper plates to prevent the direct contact between them. Thereafter the glazing system and the blinds are securely fixed in the desired place. Insulation is done on the outside of the plates and glazing system assembly so that thermal losses can be prevented. Then the constant temperature baths which circulate around the face of the two copper plates can be started.

Methodology

The temperature difference from simulated study that is on the outer pane and the inner pane is considered for temperature difference of hot and cold plate in the guarded hot plate apparatus. The sample is kept in between the hot and cold plates to find out its C-value. The measuring methodology [9] used is discussed below:

A digital volt meter and an ammeter is used to measure the heater wire voltage V and current I, respectively is used to measure the heat flux from the exposed surface of a GHP, the rate of electrical energy supplied to the heater plate Q, is determined as following

$$Q = I * V \text{ -------------- (i)}$$

The heat flux from the face of heater plate, S is then calculated by using heat flux meter output voltage,

HFMV as:

$$S = (Q - \alpha . HFMV)/Ahp \text{ -------------- (ii)}$$

Where α = heat flux meter calibration constant

Ahp = Face area of the heater plate

After the heat flux, has been measured; the glass to glass U-value of the glazing system, C (thermal resistance) can be measured as:

$$C = ((\Delta \dot{T}/S) - 2Rn)^{-1} \text{ -------------- (iii)}$$

Where ΔT = temperature difference between the warm and cold copper plate And

Rn = thermal resistance of neoprene sheet = 0.017m2 C/W The U- Value based on measurements can finally be find out as:

$$U = (C^{-1} + h_1^{-1} + h_2^{-1})^{-1} \text{ ----------- (iv)}$$

Where h1= indoor heat transfer coefficient

h2= O**utdoor** heat transfer coefficient

Results and Discussions

This investigation has been considered the extreme climate & temperature condition of India, as shown in table -3.

The main focus of this investigation was to determine the influence of different parameters viz. type glazing system (single glazing, double glazing), pane-blind spacing and climatic conditions (Hot-Dry, Hot-Humid, Cold-Dry).

The peak temperature conditions for each of these climates [8] are shown in table 6.

Table 6.Composite climate conditions

	Composite Climate Condition			
Climate Condition	**T_{out} (°C)**	**T_{in} (°C)**	**Solar Radiation W/m^2**	**Wind Speed m/s**
Hot-Dry	43	25	6570	4.815
Hot-Humid	34	25	5470	4.02
Cool-Dry	5	25	3948	3.95

Observations according to full factorial design are made by keeping one parameter fix and varying the rest parameters one by one. Both the simulated and experimental response values for the planned design are shown in the table 2.

Comparison of experimental and simulated U-Values

The investigated U-Values for single glazing system varies from 1.86 to 4.23 W/m2K where as in the case of double glazed system it varies with in the range of 1.7 to 2.28 W/m2K. Whereas the simulated U-Values for single glazing system varies from 2.24 to 5.15 W/m2K and in the case of double glazed system it varies in the range of 2.18 to 2.74 W/m2K . The environmental effects in which the guarded hot plate apparatus is located plays a vital role in due to this the experimental values are observed to be smaller by about 20% when compared to the simulated values.. The heat transfer losses tend to reduce the experimental U-values. The following is the Graphical Representation of comparison between experimental and simulated U-Values.

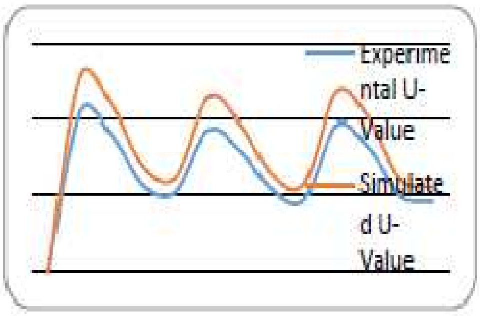

Figure 4

The effect of different glazing systems (single glazed and double glazed)

It has been clearly absorbed that by shifting from single to double glazed window, the U-Value decreases for all climatic conditions (Hot-Dry, Hot-Humid, Cold-Dry), keeping constant the pane-blind spacing and Slat angle at 0o, as the following:

Case1: The U-Value comes down by a minimum of 44% while using double glazing system in place of single glazing system for a pane-blind spacing of 20mm and Slat angle of 0o.

Case2: The U-Value reduced by a minimum of 44.8% while using double glazing system in place of single glazing system for a pane-blind spacing of 30mm and Slat angle of 0o.

Thus by adding glazing system decreases the U-value by a minimum of 44% and hence improve the thermal performance of the window. This is due to the addition of insulating layer of air which reduces the heat transfer rate in addition to absorbing the radiated heat.

The effect of spacing

By changing pane-blind spacing from 20mm to 30mm, the U-value decreases for all climatic conditions (Hot-Dry, Hot-Humid, Cold -Dry), keeping constant the type of glazing system and Slat angle at different levels, whose results are listed as under:

Case1: The U-Value decreases by a minimum of 15% while increasing the pane-blind spacing from 20mm to 30mm for a single glazed system.

Case2: The U-Value decreases by a minimum of 7% while increasing the pane-blind spacing from 20mm to 30mm for a double glazed system.

Thus increasing the space between the pane–blind the decreases U-Value. This may be due to the increase in convection between pane-blind which increase the heat transfer rate.

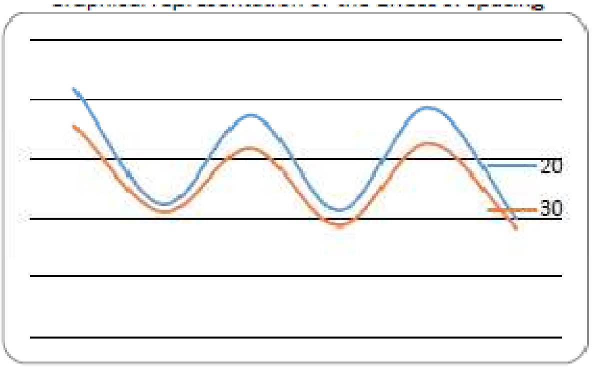

Figure 5.Graphical representation of the effect of spacing

Effect of Climate

By changing the climatic conditions from Hot-Dry to Hot-Humid and then to Cold -Dry, the U-Value decreases for all climatic conditions, keeping constant the type of glazing system and pan-blind spacing at different levels, whose results are listed as under:

Case1: The U-Value decreases by a minimum of 0.0002% while using single glazing system for a pane-blind spacing of 20mm.

Case 2: The U-Value decreases by a minimum of 0.0016% while using single glazing system for a pane-blind spacing of 30mm.

Case 3: The U-Value decreases by a minimum of 0.0068% while using double glazing system for a pane-blind spacing of 20 mm.

Case 4: The U-Value decreases by a minimum of 0.0011% while using double glazing system for a pane-blind spacing of 30 mm.

Thus by changing the climatic condtions i.e from Hot-Dry to Hot-Humid and then

Cold-Dry the U-value decreases by a less than 1% . Hence the climatic condition does not have much effect on the U-Value.

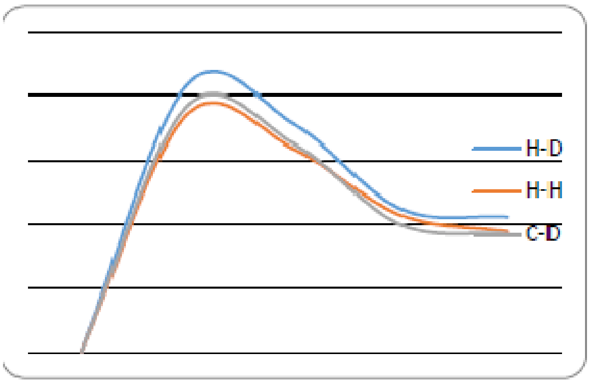

Figure 6.Graphical representation of the effect of climatic conditions on the U-value

Conclusion

As lower U-value of the glazing system is desired, the following conclusions are made from the present work:

1. Pane-blind spacing has significant impact on the U-value.
2. For Hot-Dry months in Chandigarh, double glazed windows with a pane-blind spacing of 30 mm is better as its U-Value is 2.1 W/m2K.
3. Keeping in view the greater duration of hotter months in Chandigarh, greater cooling load and also the economic feasibility, the author recommend the use of double-glazed windows with a pane spacing of 30mm for this region.

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