International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

Simulation & Thermal Analysis of Double Glazed Window with Interpane Chik Blind

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***Abstract* - Windows are designed primarily to control the indoor climate and also to provide proper ventilation. The most important objective is achieved by controlling the heat flow through the window from inside to outside in winter & from outside to inside in summer. Window solar gain has a strong influence on the building energy consumption and peak cooling load. Double glazed window are known to prevent the entry of solar gain to inside the room. Shading systems such as Venetian blinds, louver shades, draperies, bamboo blind, chik blind etc. enhances the control of solar gain through windows. In this paper the authors discussed the thermal performance of a double-glazed window with inter-pane shading device using LBNL research software WINDOWS 6. Though this type of glazing system had 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 limited. A parametric study for climatic conditions of an Indian city, Chandigarh had been made to give an insight to the thermal performance of glazing systems. In this study the effect of different parameters such as types of glazing systems (with and without shading for double glazed), pane to pane spacing (20mm, 30mm and 40mm), type of shading devices (venetian blind & chik blind) the condition of blind (no shade, open, closed) and the climatic conditions of Chandigarh for all the climate season i.e. Hot and Dry, Hot and Humid, Cold and Dry on the Thermal transmittance (U-value) is investigated.**

Key words: Double glazed window, Thermal Transmittance (U-value), , inter-pane chik blinds.

1. INTRODUCTION

Windows are the aperture the passage of light and, if not closed or sealed, also the air and sound[3]. In current times windows are usually of glazed pane or covered in some other transparent material. Window can be classified as the single glazed, double glazed windows, slider windows, awning windows, bay windows, bow windows, garden windows, picture windows, hopper windows, special shapes windows and tilt & turn windows. The figure 1.1 shows the single and double glazed window.

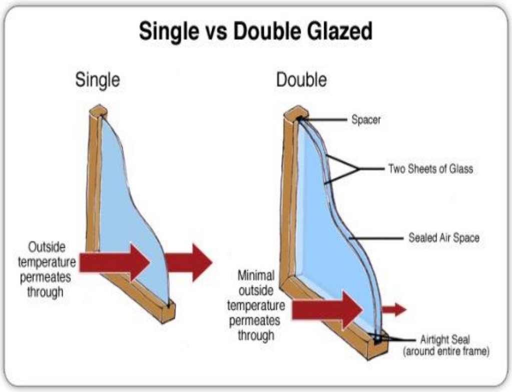

Fig. 1.1 single and double glazed window[1]

Solar gain divides into three parts as it passes through a glazing material. Some is transmitted, some is reflected, and the rest of it is absorbed. These three components decide the solar heat gain coefficient and thermal transmittance or U-value (W/m^2 k).[9].

Chik blinds are used as a inter-pane in windows to control sun-light and heat transfer up-to some extent. The presence of these shading will affect natural convection and radiant heat transfer from the window, due to which there will be a change in the heat transmission and solar heat gain, through window. Heat flows from warmer to cooler bodies, thus from inside to outside in winter, and reverses direction in summer during periods when the outside temperature is greater than indoors.

Chik blind has horizontal slats, one above another. These blinds are generally made wooden slats usually referred to as wood blinds or bamboo blinds. Whether room has wood flooring or furniture with natural finish, chik blinds shades bring harmonious texture and tones as nature intended. It is avalilable in traditional roll-ups style.

Many studies have been conducted for these types of blinds in colder countries; however their use in tropical countries like India is still 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 below figure 1.2 shows the heat transmission in windows with inter pane chik blinds. Further the heat which is transmitted is as follows: The surface 1 indicate that all three types of heat transmission conduction, convection, radiation occurs here. Conduction occurs between glazing and frame & between blinds. Some amount of heat is transmitted through windows and some gets reflected via inter pane chik blinds.

The blinds are placed between surface 2 and surface 3 as shown in the figure. Some amount of heat is absorbed by glazes. The blinds are used to reduce the heat transmit through window.

The convection occurs here between outside air and external window pane that is surface1.Further the heat is transmitted in inter pane & interior window pane inside the cavity and inter slat surface spaces.

Radiation occur between surrounding and external/internal window pane, between blinds of internal /external pane and between the cavities.

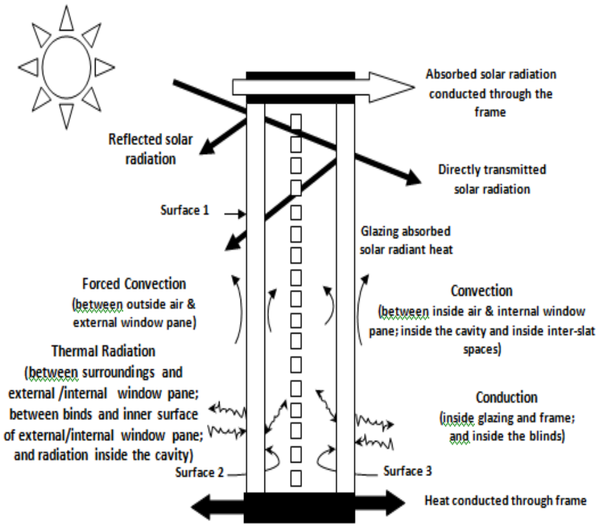

Fig.1.2: Energy Interactions in Double Glazed Windows with chik Blinds[5]

For the present research of Double glazed window, the chik blinds which is made up of Bamboo, an Indian shading device is been identified for the calculation of thermal performance using WINDOWS 6 Software.

2. EXPERIMENTAL STUDY

The various solar/optical properties which can affect the heat transfer radiation through glazing panes is transmittance, absorbance and reflectance. These properties can be determined using UV-VIS-NIR Spectrophotometer with integrating sphere.

UV-VIS-NIR Spectrophotometer

Every chemical compound/material absorbs, transmits, or reflects light over a certain range of wavelength. Spectrophotometery is a measurement of how much a chemical substance/material absorbs, transmits or reflects light. A cary 5000 UV-VIS-NIR spectrophotometer can be considered for calculationg sola/optical properties[6]. Further the results are calculated in terms of percentage. For the current study lambda 1050 PerkinElmer UV-VIS-NIR spectrophotometer with integrating sphere of 150 mm diameter is considered.

Principle of UV-VIS-NIR Spectrophotometer

It is based upon the principle of Beer Lambert's law which state that "when a beam of monochromatic light is passed through a solution of an absorbing substance, the rate of decrease of intensity of radiation with thickness of the absorbing solution is proportional to the incident radiation as well as the concentration of the solution.'' Thus greater the number of molecules capable of absorbing light of a given wavelength, the greater the extent of light absorption. This is the basic principle of UV spectroscopy.

Components of the UV-VIS-NIR Spectrophotometer

a) Light Source

Tungsten filament lamps and Hydrogen-Deuterium lamps are most widely used and suitable light source as they cover the whole UV region. Tungsten filament lamps are rich in red radiations.

b) Monochromator

Monochromators generally composed of prisms and slits. The most of the spectrophotometers are double beam spectrophotometers. The radiation emitted from the primary source is dispersed with the help of rotating prisms. The various wavelengths of the light source which are separated by the prism are then selected by the slits such the rotation of the prism results in a series of continuously increasing wavelength to pass through the slits for recording purpose.

c) Detector

Generally two photocells serve the purpose of detector in UV spectroscopy as in fig. 2.1. One of the photocell receives the beam from sample cell and second detector receives the beam from the reference. The intensity of the radiation from the reference cell is stronger than the beam of sample cell. This results in the generation of pulsating or alternating currents in the photocells.

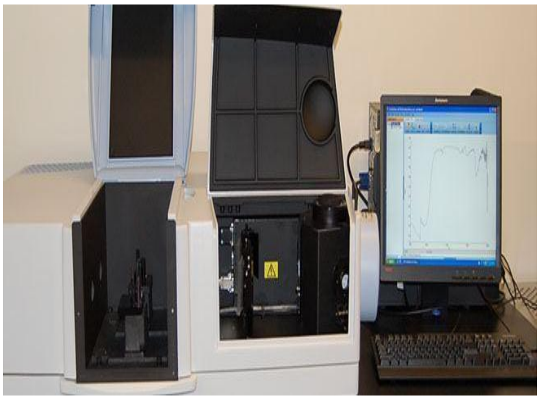

Fig. 2.1:Perkin Elmer Lambda 1050 Spectrophotometer

d)Integrating Sphere

An integrating sphere (IS) is an optical component consisting of a hollow spherical cavity with its interior covered with a diffuse white reflective coating, with small holes for entrance and exit ports. The Integrating sphere is mainly used since it can use to resolve or collect all scattered beam of incident radiation to focus on a single point for the calculation of transmittance and reflection of the sample. When the light beam is passed through IS its

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

get scattered through the inner surface in all respective angles. The detector is attached in the IS recollect the scattered beam which can further calculate the optical properties of the sample. Integrating sphere is shown in fig. 2.2

Fig. 2.2: Integrating Sphere

3. MEASUREMENT PROCEDURE

The value of transmittance, reflectance, and emissivity are determined in the following ways:

3.1 Measurement Procedure of determining Transmittance

1. Initially we have to turn on the power supply for UV-VIS-NIR spectrophotometer and at least before 20 minutes prior to testing.
2. Then place the sample in the sample port and fix it with the clips been provided.
3. Then with the help of UV-Win lab software enter all the essential data for particular type of measurement.
4. In this procedure, first enter into data collection and insert the required details.
5. Enter the wavelength scan range, for the current study wavelength range from 300-2500 nm has been taken.
6. Then ordinate mode can be chosen for %T, the transmittance is simulated in percentage.
7. Further click ok, the simulation for the transmittance sample will be formulated on computer screen by UV win-lab software.
8. With the help of integrating sphere scattering of beam which deviates from the optical path is resolve and is recollected and true measurement for the total transmittance can be achieved. The transmittance determined from the peak value attained with the experimental study. Thus the transmittance value determines is 0.41 in the wavelength range of 300 nm-2400 nm. The transmittance determine in the range 300nm-2400nm is shown in fig. 3.1.

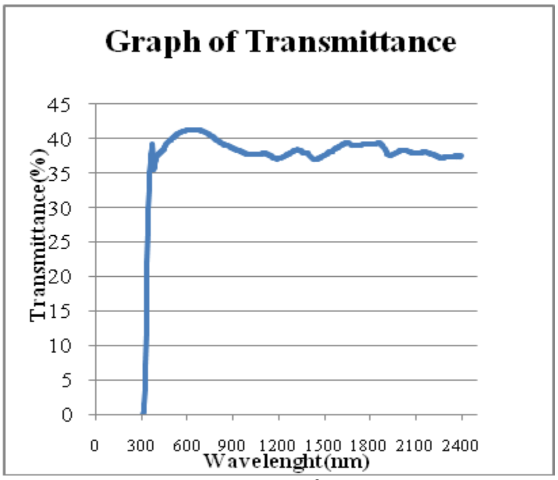

Fig. 3.1: Determining of Transmittance

3.2 Measurement Procedure of determining Reflectance

1. Initial steps are same of as which are discuss above for measuring transmittance.
2. In measuring the reflectance the sample is place back side of the sphere and the light reflected back off the sample and collected by the sphere. The latter measurement are achieved by the allowing the Specular component to exit the sphere through the open Specular port.
3. Further the simulation is formulated on the computer screen with the help of UV win-lab software.
4. The reflectance 0.44 in the wavelength 300 nm-2400 nm, determined from the peak value attain with a experimental study is shown in fig. 3.2

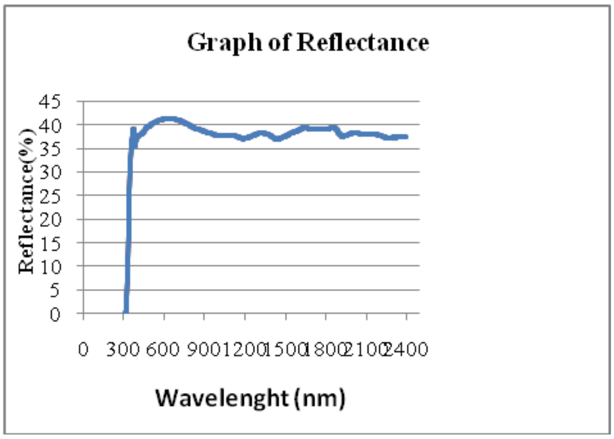

Fig. 3.2: Determining of Reflectance

3.3 Emissivity Measurement

The emissivity is to be resolute through the Infrared Thermometer calibrated along with a digital Thermometer. A infrared thermometer is the one which measures the temperature from a particular portion of the thermal radiation which is emitted by the body,they are also known as laser thermometers, if a laser is use to aim the laser light on the object which in return measure the temperature of non-contact body from a distance. The infrared thermometer have a lens to focus IR(infrared) laser light on detector which inreturns convert the light source energy to a electrical indicator which can be displayed as a unit of temperature on IR thermometer screen.

3.4 Emissivity Testing by IR Thermometer

Different methods can be considered for determining the emissivity of a material. One can be able to know the emissivity of many often used materials readily available in standard books. Emissivity tables in these books too assist us to know the accurate wavelength range of a known material. Mostly in the case of metals, the values within this tables must simply be used for point of reference purposes because the situation of the surface (e.g. polished, oxidized or scaled) can control emissivity other than the different material themselves.

3.5 Procedure to Determine Emissivity

Warm up a model of the material to a identified temperature moreover whose temperature be able to determine same temperature incredibly correctly using a digital thermometer. Next determine the aim temperature through the IR thermometer. Adjust the emissivity in anticipation of the temperature correspond to that of the digital thermometer. Presently continue this emissivity[8].

4. MODELLING & SIMULATION

4.1 Overview of WINDOWS 6.0 Software

For simulate the heat transfer throughout double-glazed windows with inter-pane chik blinds, Window 6.0 software is considered, which is freely obtainable from LBNL WINDOW, in PC companionable computer program, discovered by the building technologies group in the Lawrence Berkeley Laboratory. This software is helpful in simulating the thermal and optical properties essential for heat transfer analysis of glazing products. Latest materials with measured thermal and solar/optical properties can also be import in the software data record. Many simulation changes can be implement in this software for simulating models of different glazing systems. The input parameters which can be altered which includes;spacing between glazing layers, type of blinds, slat angles, type of pane, ecological conditions, air gap in stuck between the panes and so many more.

4.2 Simulation

The simulation is considered on the basis of input parameters factor approach which is include the effect of control input parametrs on response output parameters in LBNL research software WINDOWS 6. The glazing panes of size 635 x 635 mm is chosen for simulation for different glazing systems.[4] The condition of blind is open and closed. Different input simulation input factors are shown in table 1. The geometrical properties of Chik blinds are shown in table 2.

Table 1: Control Parameter & Assigned levels

Levels	Glazing Type	Pane spacing (mm)	Condition of Blind	Climate
1	A- DGW without inter- pane blinds	20	Open	Hot-Dry
2	B- DGW with inter-pane Venetian blinds	30	Close	Hot-Humid
3	C- DGW with inter-pane chik blinds	40	Close	Cold-Dry

Table 2: Geometrical properties of Chik blinds

Name	Position	Slat width (mm)	Thickness (mm)	Spacing (mm)	Color
Chik Blind	Horizontal	2	4	2.5	Opaque Brown

The chik blinds properties are described in the above table is used for the calculation of its solar/optical properties. The solar/optical properties of transmittance, reflectance & emissivity for chik blinds are shown in table 3.

Table 3:Solar/optical properties of chik blinds

Description		Chick blinds
Solar	Trans, Front (T_{sol})	0.41
	Trans, Back (T_{sol}^2)	0.41
	Reflection Front (R_{sol})	0.44
	Reflection Back (R_{sol}^2)	0.44
Visible	Trans, Front (T_{vis})	0.41
	Trans, Back (T_{vis}^2)	0.41
	Reflection Front (R_{vis})	0.44
	Reflection Back (R_{vis})	0.44
IR	Emis, Front (Emis1)	0.95
	Emis, Back (Emis2)	0.95

5. RESULTS & DISCUSSION

Simulation results were carried out, as the comparison of double glazed window without shading and double glazed window with inter-pane shading of venetian blind and chik blind, has been investigated by the simulation carried out in WINDOWS 6 Software.

The glazing system A, B & C are defined as follows:

1. A - Double glazed window without inter-pane.
2. B -Double glazed window with inter-pane shading of venetian blind.
3. C - Double glazed window with inter-pane shading of chik blind.

5.1The Effect of Glazing Systems

When shifting from double glazed without shading device to double glazed window with inter-pane shading, the U-Value reduce for all climatic conditions (Hot-Dry, Hot-Humid, Cold-Dry), by maintain constant pane spacing and condition of blind when open or close, outcome results are shown in Table 4.

Table 4: Effect of glazing system on U-Value

Season	Spacing (mm)	Condition of Blind	A/ C	B
Hot Dry	20	Open	3.08	2.47
Hot Humid	20	Open	2.86	2.31
Cold Dry	20	Open	2.68	2.17
Hot Dry	20	Close	2.36	2.39
Hot Humid	20	Close	2.21	2.23
Cold Dry	20	Close	2.09	2.09
Hot Dry	30	Open	3.03	2.35
Hot Humid	30	Open	2.82	2.20
Cold Dry	30	Open	2.66	2.06
Hot Dry	30	Close	2.24	2.32

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Season	Spacing (mm)	Condition of Blind	A/ C	B
Hot Humid	30	Close	2.15	2.10
Cold Dry	30	Close	1.97	1.97
Hot Dry	40	Open	3.04	2.29
Hot Humid	40	Open	2.84	2.03
Cold Dry	40	Open	2.68	2.00
Hot Dry	40	Close	2.18	2.23
Hot Humid	40	Close	2.03	2.03
Cold Dry	40	Close	1.90	1.90

Case 1: The U- Value increases by approx 20% (for any season) while using glazing system B in open condition of blinds (slat angle 0°) in position of glazing system A ,used for a pane spacing of 20 mm.
Case 2: The U- Value increases from approx 20% to 23% (for any season) while using glazing system B in open condition of blinds (slat angle 0°) in position of glazing system A used,for a pane spacing of 30 mm.
Case 3: The U- Value increases from approx 25% to 28% (for any season) while using glazing system B in open condition of blinds (slat angle 0°) in position of glazing system A for a pane spacing of 40 mm..
Case 4: The U- Value decreases by a least amount of 1.3 %(for any season) via glazing system C in closed condition of chik blinds in place of glazing system B in closed condition (slat angle 90°) for a pane-pane spacing of 20 mm.
Case 5: The U- Value decreases by a least amount of 2.86% (for any season) via glazing system C in closed condition of chik blinds in place of glazing system B in closed condition (slat angle 90°) for a pane-pane spacing of 30 mm.
Case 6: The U- Value decreases by a least amount of 2.2% (for any season) while using glazing system C in closed condition of chik blinds in position of glazing system B in closed condition (slat angle 90°) for a pane-pane spacing of 40 mm.

From the above result it as concluded that where light is a major requirement the venetian blind as inter-pane shading are preferably used and where heating/cooling(energy are major concern chik blind with inter-pane shading may be prefer over venetian blind. Effect of glazing system on U-value in shown in fig. 5.1

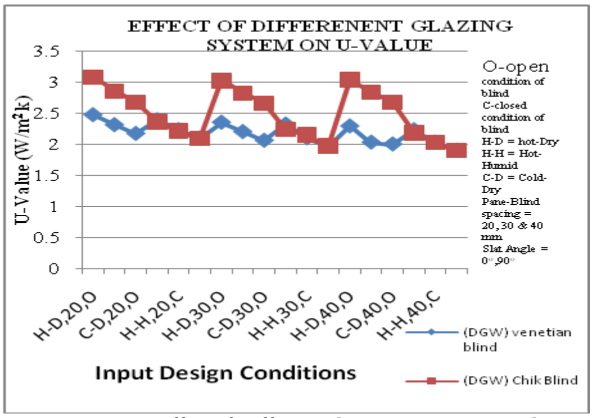

Fig.5.1: Effect of Different Glazing System on U-value

5.2 The Effect of Spacing

When shifting pane spacing from 20mm to 30mm and followed by to 40mmm, the U- Value decrease for all climatic conditions (Hot-Dry, Hot-Humid, Cold -Dry), maintain stable type of glazing system and condition of blind at open and closed condition outcome results are shown in Table 5.

Table 5: Effect of spacing

Type of Glazing	Climatic Condition	Condition of Blind	Spacing (mm)		
			20	30	40
A	Hot Dry	No Shade	3.08	3.03	3.04
A	Hot Humid	No Shade	2.86	2.82	2.84
A	Cold Dry	No Shade	2.68	2.66	2.68
B	Hot Dry	Open	2.47	2.35	2.29
B	Hot Humid	Open	2.31	2.20	2.13
B	Cold Dry	Open	2.17	2.06	2.00
B	Hot Dry	Closed	2.39	2.32	2.21
B	Hot Humid	Closed	2.23	2.10	2.03
B	Cold Dry	Closed	2.09	1.97	1.90
C	Hot Dry	Closed	2.36	2.24	2.18
C	Hot Humid	Closed	2.21	2.15	2.03
C	Cold Dry	Closed	2.08	1.97	1.90

Case 1: The U- Value decreases by 1.6% (for any season) whereas increase the pane spacing from 20 mm to 30 mm and after that increase by 0.3 % to 40 mm for a double glazed system without shading.
Case 2: The U- Value decreases by 4% (for any season) whereas increase the pane spacing from 20 mm to 30 mm and after that decreases by 3% to 40 mm for a double glazed system with inter-pane shading of venetian blind in open condition.
Case 3: The U- Value decreases by 5% (for any season) whereas increase the pane spacing from 20 mm to 30 mm and after that decrease by3.5% to 40 mm for a double glazed system with inter-pane shading of venetian blind in close condition.
Case 4: The U- Value decreases by 5% (for any season) whereas increase the pane spacing from 20 mm to 30 mm and after that decrease by 3.5% to 40 mm for a double glazed system with inter-pane shading of chik blind in close condition.

If pane spacing of 40 mm is to be used in closed condition, chick blind to be prefer when compared to venetian blind with a pane spacing of 40mm.however this gain in reduction of U-value should be weighed in the light of economic feasibility for using 40 mm spacing. Effect of spacing on U-value is shown graphically in Fig. 5.2.

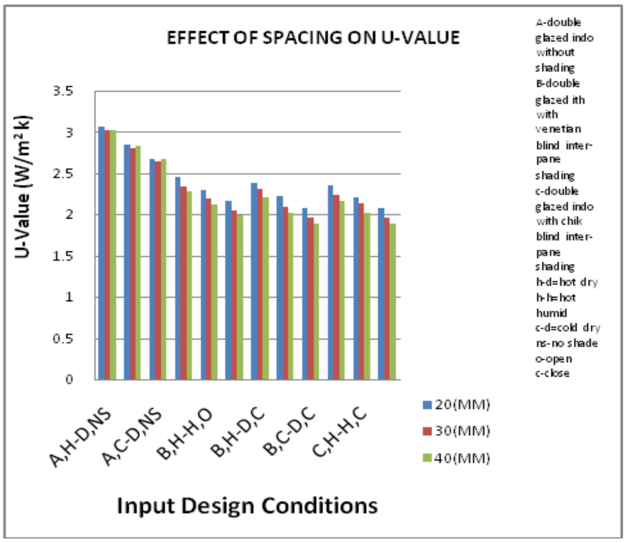

Fig. 5.2 : Effect of Spacing on U-value

5.3 Effect of condition of Blinds

The U- Value is reduce while shifting from open to close for condition of blind. The consequences of the effects of condition of blinds are been listed in Table 6.

Table 6: Effect of condition of blinds

Control Parameters			Condition of blinds	
Season	Spacing	Type of Glazing	Open	Close
Hot-Dry	20	B	2.47	2.39
Hot-Humid	20	B	2.31	2.23
Cold-Dry	20	B	2.68	2.08
Hot-Dry	20	C	3.08	2.36
Hot-Humid	20	C	2.86	2.21
Cold-Dry	20	C	2.17	2.09
Hot-Dry	30	B	2.35	2.32
Hot-Humid	30	B	2.20	2.10
Cold-Dry	30	B	2.66	1.97
Hot-Dry	30	C	3.03	2.24
Hot-Humid	30	C	2.82	2.15
Cold-Dry	30	C	2.06	1.97
Hot-Dry	40	B	2.29	2.23
Hot-Humid	40	B	2.13	2.03
Cold-Dry	40	B	2.00	1.90
Hot-Dry	40	C	3.04	2.18
Hot-Humid	40	C	2.84	2.03
Cold-Dry	40	C	2.68	1.90

Case1: For glazing system B, while changing the condition of blind from open to close for a pane spacing of 20 mm, the U-value decrease by 3% for hot dry and hot humid climate whereas it decrease by 22% for cold dry climate.

Case 2: For glazing system C, while changing the condition of blind from open to close for a pane spacing of 20 mm, the U-value decrease by 22% for hot dry and hot humid climate whereas it decrease by 3% for cold dry climate.

Case 3: For glazing system B, while changing the condition of blind from open to close for a pane spacing of 30 mm, the U-value decrease by 4.5% for hot dry and hot humid climate whereas it decrease by 25% for cold dry climate.

Case 4: For glazing system C, while changing the condition of blind from open to close for a pane spacing of 30 mm, the U-value decrease by 24.5% for hot dry and hot humid climate whereas it decrease by 4% for cold dry climate.

Case 5: For glazing system B, while changing the condition of blind from open to close for a pane spacing of 40 mm, the U-value decrease by 4% (for any season).

Case 6: For glazing system C, while changing the condition of blind from open to close for a pane spacing of 40 mm, the U-value decrease by 24% (for any season).

Thus we can conclude that maximum decrease takes place by chik blind i.e. glazing system c when used in closed condition for hot dry climate hence the performance of glazing system can be increased the effect of condition of blind is graphically shown in Fig.5.3.

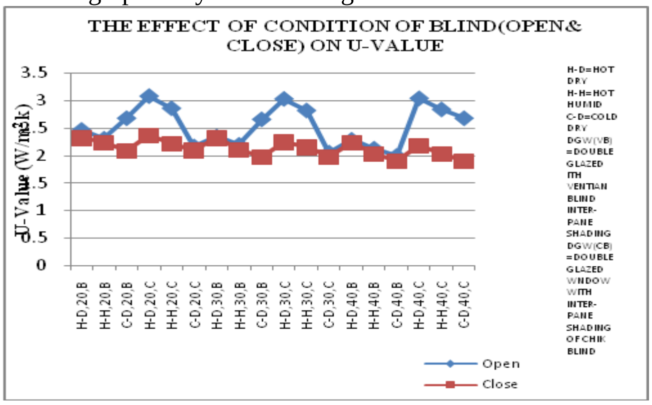

Fig. 5.3: Effect of condition of Blind on U-value

5.4 Effect of Climate

When shifting the climatic conditions from Hot-Dry to Hot-Humid and next to Cold -Dry, the U- Value decrease for all climatic conditions, maintain stable the type of glazing system and pane spacing at different level, whose results are listed in Table 7.

Table 7: Effect of different climate

Type of Glazing	Spacing (mm)	condition of Blind	Hot Dry	Hot Humid	Cold Dry
A	20	No shade	3.08	2.86	2.68
A	30	No shade	3.03	2.82	2.66
A	40	No shade	3.04	2.84	2.68
B	20	Open	2.47	2.31	2.17
B	30	Open	2.35	2.20	2.06
B	40	Open	2.29	2.13	2.00
B	20	Closed	2.39	2.23	2.09
B	30	Closed	2.32	2.10	1.97
B	40	Closed	2.23	2.03	1.90
C	20	Closed	2.36	2.21	2.08
C	30	Closed	2.24	2.15	1.97
C	40	Closed	2.18	2.03	1.90

Case 1: The U- Value decreases by 7.1% with the change in climate from hot dry to hot humid and further decrease by 6% when the climate change to cold climate with pane spacing of 20 mm for glazing system A.

Case 2: The U- Value decreases by 6.5% with the change in climate from hot dry to hot humid and further decrease by 5.6 % when the climate change to cold climate with pane spacing of 30 mm & 40 mm for glazing system A.

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ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

Case 3: The U- Value decreases by 6.7% with the change in climate from hot dry to hot humid and further decrease by 5.6 % when the climate change to cold climate with pane spacing of 20 mm, 30 mm & 40 mm for glazing system B in open condition.

Case 4: The U- Value decreases by 6.5% with the change in any season for pane spacing of 20 mm and further decrease by 7.6 % in any season with pane spacing of 30 mm & 40 mm for glazing system B in close condition.

Case 5: The U- Value decreases by 6.5% with the change in any season for pane spacing of 40 mm and further decrease by 4% - 8 % in any season with pane spacing of 20 mm & 30 mm for glazing system C in close condition.

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 5% - 6% . Hence the climatic condition does not have much effect on the U- Value,the effect of climate is graphically shown in Fig. 5.4.

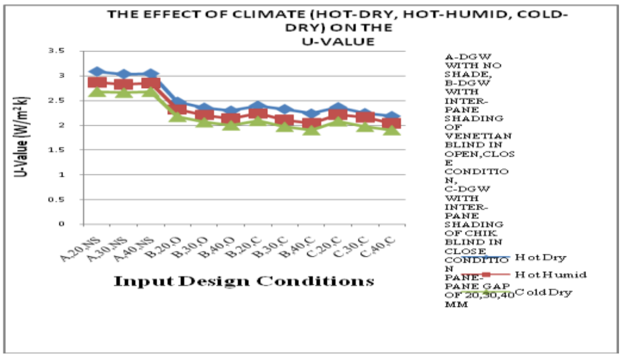

Fig. 5.4: The effect of climate (hot-dry, hot-humid, cold dry) on U-value

Thus all the four effects on U-value viz. effect of glazing system, effect of spacing, effect of different condition on blinds, & effect of different climates are described above.

6. CONCLUSION

The lesser U- Value for the glazing system shows that, the following conclusions made from the present investigation:

1. When light is a major requirement the venetian blind as inter-pane shading are preferably used and where heating/cooling (energy are major concern chik blind with inter-pane shading may be prefer over venetians.
2. If pane spacing of 40 mm is to be used in closed condition, chick blind to be preferred as compared to venetian blind with a pane spacing of 40 mm. However this gain in reduction of U-value should be weighed in the light of economic feasibility for using 40 mm spacing.
3. The maximum decrease takes place by chik blind i.e. glazing system c when used in closed condition for hot dry climate hence the performance of glazing system can be increased the effect of condition of blind.
4. Hence by varying the climatic condtions i.e from Hot-Dry to Hot-Humid and next to Cold-Dry the U- Value decrease by a a smaller amount 5% -6% . Hence the climatic condition does not have much effect on the U - Value.

So the authors concluded that glazing system C (double glazed window with inter-pane shading of chik blind) decrease the maximum heating affect in hot-dry condition when used in close condition, though 40 mm reduction are higher but taking in consideration it is advisably of high cost, so the 30 mm pane spacing with close condition is better for hot dry climate.

REFERENCES

[1] http://www.sustainablehomes.ie/energy-insulation/windows-doors-porches.
[2] Pierre Bouguer, Essai d'optique sur la gradation de la lumière (Paris, France: Claude Jombert, pp. 16–22.1729)
[3] https://en.wikipedia.org/wiki/Window.
[4] Vijay Kumar, & Anuranjan Sharda, "Experimental Investigation Of Heat Transfer Through Windows With Interior Blinds", International Journal of Research in Engineering and Technology, vol 02 (76-85) 2013.
[5] Statistical evaluation of U-value of a window with inter-pane blinds, "Anuranjan Sharda and Sudhir Kumar", Science and Technology for the Built Environment International Journal of Ambient Energy, vo l21, 179–189, 2015
[6] Michael R. Collins, Tao Jiang, "Validation of Solar/Optical Models for Louvered Shades Using a Broad Area Illumination Integrating Sphere", ASHRAE. Vol ppt 145-154, 2008.
[7] Nathan A. Kotey John L. Wright, Michael R. Collins, "Determining Off-Normal Solar Optical Properties of Roller Blinds", ASHRAE vol 483-490, 2008
[8] Principle of non-contact temperature by RAYTEK. Klaus-Dieter Gruner,2003.
[9] Anuranjan Sharda, Dr. Sudhir Kumar "Heat transfer through windows: A Review" International Conference on Advances in Mechanical Engineering, August 3-5, 2009.