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ScienceDirect
Building and Environment 43 (2008) 1596–1602
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

Different glazing systems and their impact on human thermal comfort—Indian scenario

M.C. Singh[a], S.N. Garg[a,*], Ranjna Jha[b]

[a]Centre for Energy Studies, Indian Institute of Technology (Hauz Khas), New Delhi 110016, India
[b]Netaji Subash Institute of Technology, Dwarka, New Delhi 110059, India

Received 8 May 2007; received in revised form 4 October 2007; accepted 7 October 2007

Abstract

In the present communication, fifteen different glazing systems ranging from 3 mm single glazed clear glass to double glazed with low-e and solar control coating, have been analysed in terms of their human thermal comfort impact. Thermal comfort is measured in term of PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied). Study encompasses all the six climatic zones of India. By using OPTICS 5.0 and WINDOW 5.0, *U*-values, solar heat gain coefficient, inside glazing surface temperatures and inside solar radiation have been computed. Depending upon different climatic zones, six sets of different design conditions, in terms of ambient temperatures, solar radiation and wind velocity, have been chosen. Typical values of metabolic rate and clothing insulation taken are 1.2 met and 0.5 clo for summer and 1.0 met and 1.0 clo for winter, respectively. Inside room air velocity is taken as $0.15\,m\,s^{-1}$ round the year. Room temperature is taken as 20 °C in winter and 25 °C in summer. It is found that for cold station (e.g. Leh) all glazings except solar control glazings, ensure thermal comfort and total PPD is less than 10% ($|PMV| \leqslant 0.5$). For warm and hot climates, solar control glazings are thermally suitable. Results for winter night of Delhi shows that all the 15 glazings are inadequate for thermal comfort and PPD, due to cold feeling, varies between 27% and 33% approximately.

Keywords: Thermal comfort; Glazings; Climatic zones; PPD; PMV

1. Introduction

This manuscript describes the impact of different windows on human thermal comfort. This impact is in three ways: the long-wave heat exchange between human body and window inside surface, short wave (solar) radiation which penetrates through window glass and falls on the human body [1–4], and drafts induced by cold air drainage off the window surface [5]. Although windows are not the main element to decide human thermal comfort, but when their inside surfaces are very hot or cold, the building occupant is very close to the window or when solar radiation through the window is very high, their influence becomes significant. This work has been done for Indian climatic conditions and as here, winter conditions are not so severe, so drafts effect is not so significant and not included in this study.

Fifteen types of windows, ranging from 3 mm clear glass to double-glazed solar control and low-e windows, whose optical data were made available by the window manufacturers in India, have been analysed. India is divided in six climatic zones and one representative station for each climatic zone was chosen [6]. Their geographical parameters, along with their environmental conditions are shown in Table 1. Ten year weather data (1990–1999) which include hourly values of global and diffuse radiation, ambient temperature and wind velocity was obtained from Indian Meteorological Department (IMD), Pune, and this data conform to international standards. Design conditions for each climatic zone are selected on the basis of 2% annual cumulative frequency, as described in [7]. The solar radiation includes both beam and diffuse radiation falling on glazing surface and it is calculated as per HDKR method [8]. For all the 15 types of windows and with the

*Corresponding author. Tel.: +91 11 26596411; fax: +91 11 26581121.
E-mail addresses: mahbsr@yahoo.co.in (M.C. Singh), sngarg@ces.iitd.ernet.in (S.N. Garg), drranjnajha@yahoo.com (R. Jha).

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doi:10.1016/j.buildenv.2007.10.004

Table 1
Environmental conditions for different stations used in this study and other related input data

S. no.	Climate	Station	Ambient temperature (°C)	Wind speed ($m\,s^{-1}$)	Vertical global radiation ($W\,m^{-2}$)
1	(a) Composite summer	New Delhi (28°35′N, 77°12′E)	40.0	4.1	555
	(b) Composite winter	New Delhi (28°35′N, 77°12′E)	10.6	2.3	448
2	Warm and humid	Mumbai (18°54′N, 72°49′E)	33.7	4.1	537
3	Cold and sunny	Leh (34°09′N, 77°34′E)	−8.4	1.9	521
4	Moderate	Bangalore (12°58′N, 77°35′E)	33.5	4.9	507
5	Hot and dry	Jodhpur (26°18′N, 73°01′E)	40.1	5.1	577
6	Cold and cloudy	Shillong (25°34′N, 91°53′E)	8.2	1.0	367

Room temperature: 20 °C (winter) and 25 °C (summer).
Clothing insulation: 1.0 clo (winter) and 0.5 clo (summer).
Metabolic rate: 1.0 met (winter) and 1.2 met (summer).
Inside room air velocity: 0.15 $m\,s^{-1}$ for all seasons.

Table 2
Different glazing systems and their thermo-optical parameters

Glazing no.	Glazing type	Glazing abbreviation	*U*-value ($W\,m^{-2}\,K^{-1}$)	SHGC (*g*-value)
1	Single, 3 mm, clear	S Cl 3	5.74	0.87
2	Single, 6 mm, clear	S Cl 6	5.65	0.83
3	Single, 6 mm, bronze	S Brz	5.65	0.60
4	Single, 6 mm, grey	S Gry	5.65	0.57
5	Single, 6 mm, green	S Grn	5.65	0.59
6	Double, 6 mm, 12 mm air, clear	D Cl	2.95	0.73
7	Double, 6 mm, bronze, 12 mm air, clear	D Brz	2.95	0.49
8	Double, 6 mm, grey, 12 mm air, clear	D Gry	2.95	0.47
9	Double, 6 mm, green, 12 mm air, clear	D Grn	2.95	0.49
10	Double, 6 mm, absorbing film coated, 12 mm air, clear*	D A SC	2.90	0.35
11	Double, 6 mm, absorbing film coated, 12 mm air, clear*	D A SC	2.80	0.24
12	Double, 6 mm, absorbing film coated, 12 mm air, clear*	D A SC	2.77	0.22
13	Double, 6 mm, reflective film coated, 12 mm air, clear	D R SC	1.95	0.10
14	Double, 6 mm, low-e coated, 12 mm air, clear	D LE 1	1.74	0.54
15	Double, 6 mm, low-e coated, 12 mm air, clear	D LE 2	1.63	0.52

U-values and solar heat gain coefficients, SHGC, are obtained from WINDOW 5.0.
*Glazing films and their spectral properties are different and hence different SHGC.

manufacturer provided data, a window library is created in OPTICS 5.0 [9] and this library is imported in WINDOW 5.0 [10,11] and then one obtains *U*-value ($W\,m^{-2}\,{}^{\circ}C^{-1}$), solar heat gain coefficient (*g*-value) and inside glass surface temperature. The calculation method is described in [12] and the results so obtained are shown in Table 2. Every window is associated with a glazing abbreviation in order to distinguish it from others easily (e.g. D A SC means double, absorbing, solar control window). Also the windows are arranged in the order of their decreasing *U*-values. The other parameters used are: room dimensions, 4 m × 4 m × 3 m; glazed area, 100% of wall area; relative humidity, 50%; inside air velocity, 0.15 $m\,s^{-1}$; clothing insulation, 0.5 clo (summer) and 1.0 clo (winter); metabolic rate 1.2 met (summer) and 1.0 met (winter); solar absorptance of person 0.6; emittance of the human body, 0.97; and projected area factor of person, 0.3. The person is seated 1 m away from the window which occupies entire external facade (4 m × 3 m). Window means here only glazing without frame. All the internal surfaces of the room are assumed to be at the same temperature as room air. Room air temperature is taken 20 °C for winter conditions and 25 °C for summer conditions.

2. Methodology

PMV is calculated according to [13] as

$$\begin{aligned}\mathrm{PMV} = {} & (0.303\mathrm{e}^{-0.036\mathrm{M}} + 0.028) \\ & \times[M(1-\eta) - 3.05\times10^{-3}(5733 - 6.99\,M(1-\eta) - P_{\mathrm{a}}) \\ & - 0.42(M(1-\eta) - 58.15) - 1.7\times10^{-5}M(5867 - P_{\mathrm{a}}) \\ & - 0.0014\,M(34 - T_{\mathrm{air}}) - 3.96\times10^{-8}f_{\mathrm{cl}}((T_{\mathrm{cl}}+273)^4 \\ & - (T_{\mathrm{mrt}}+273)^4) - f_{\mathrm{cl}}h_{\mathrm{c}}(T_{\mathrm{cl}} - T_{\mathrm{air}})], \qquad (1)\end{aligned}$$

where M is the metabolic rate per unit body area ($W\,m^{-2}$), P_a stands for partial vapour pressure (Pa), f_{cl} is the clothing area factor, T_{mrt} is the mean radiant temperature (°C) calculated as per [3,7], T_{air} stands for inside air temperature (°C), T_{cl} is the clothing surface temperature (°C), h_c stands