Available online at www.sciencedirect.com
ScienceDirect
Procedia Technology 23 (2016) 439 – 446
Procedia Technology

3rd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2016

Effect of Window Overhang shade on Heat gain of Various Single Glazing Window glasses for Passive Cooling

Saboor Shaik[a]*, KiranKumar Gorantla[b], Ashok Babu Talanki Puttaranga Setty[c]

[a,b,c] *Department of Mechanical Engineering, National Institute of Technology Karntaka, Surathkal, Mangalore-575025, Karnataka, India.*

Abstract

This paper presents thermal performance of various single glazing window glasses covered with and without window overhang shading. Buildings are designed with laterite stone walls with different dimensions of overhang shading devices on single glazing windows in four different climatic zones of India: Ahmedabad (Hot & dry), Bangalore (moderate), Calcutta (warm & humid) and Hyderabad (composite). In this study, five glass materials such as clear, bronze, green, grey and blue-green were selected. Total three hundred and twenty building models with and without window overhangs were designed in four climatic zones of India using Design builder 4.3.0.039. Thermal simulation was carried out in Energy plus 8.1 simulation tool. From the results, it is observed that laterite buildings with grey glass window with 1.5m overhang shading device were found to be energy efficient from the least heat gain point of view in south direction among three hundred and twenty building models studied in four climatic zones of India. The results of the study help in selecting the best window glass material and also help in selecting appropriate dimensions for overhang shading device for reducing cooling loads in buildings.

Peer-review under responsibility of the organizing committee of ICIAME 2016

Keywords:

* Corresponding author. Tel: +91-9880452903; fax: +91-0824-2474000-3664.
E-mail address: saboor.nitk@gmail.com

2212-0173
Peer-review under responsibility of the organizing committee of ICIAME 2016
doi:10.1016/j.protcy.2016.03.048

1. Introduction

The commercial and residential sectors account for more than 30% of energy consumption in India. Passive buildings can consume 40 to 60% less power than conventional buildings [1]. The Façade shading and fenestration shading play significant role in reducing insolation and heat gain in buildings. Earlier, the detailed study has been carried out to compute overall heat transfer coefficient, solar heat gain coefficient and visual transmittance values of various window glasses using Window 4.1 tool [2]. The effect of location of the various insulation materials within the external roof exposed to direct solar radiation on unsteady thermal properties was studied in detail [3]. The significance of optical and thermal properties of glass materials for thermal and visual comfort was reported [4]. The studies on the optimum inward glass tilt angle for window glass to gain minimum heat in buildings were reported [5]. The modelling of a single and double glazing window glasses using the radiation element method was presented [6]. The air gap thickness studies in the external wall were carried out in the literature [7]. The effect of louver shading for glass window was studied in detail [8]. The effect of shading devices on air temperature and visual environment in Jordan climatic conditions was reported [9]. This study mainly focuses on fenestration shading. The present study presents the thermal performance of various glass windows with different window overhang dimensions to gain minimum heat in buildings of four different climatic zones of India. The simulations were carried out on peak summer day of the cities in each climatic zone [10,11].

Nomenclature

a_s	solar absorptance of the surface	I_g	Intensity of ground reflected diffuse radiation
D	Density (kg/m^3)	I_{sky}	Intensity of sky diffuse radiation
C_p	Specific heat (J/kgK)	F_{sgrd}	Angle factor between the surface and the ground
K	Thermal conductivity (W/mK)	I_T	Total incident radiation (direct +diffuse+ ground)
S	Area of the surface	F_{ssky}	Angle factor between the surface and the sky
S_s	Sunlit area	α	solar absorptance
U	Overall heat transfer coefficient	ρ	solar reflectance
Q_{so}	Solar gain on any exterior surface	τ	solar transmittance
I_b	Intensity of beam (direct) radiation	τ_s	solar thermal transmittance of the windowglass
α_s	Solar thermal reflectance of the windowglass		

2. Design methodology

The building models with different single glazing glass windows shaded by various dimensions of overhangs were designed in Design builder version 4.3.0.039. The building walls are designed with laterite stone. The dimensions of the building models are 4 m X 4 m X 4 m with 0.245 m laterite wall thickness. The walls of the building models were covered inside and outside, by 0.0125 m plaster. The floor was designed with dense concrete with 0.15 m thickness and 0.0125 m cement plaster was added at inner side of the building. The roof was designed with reinforced cement concrete of 0.15m thickness and cement plaster was added at the inner and outer side of the building with 0.0125 m thickness. Solar thermal properties of different window glass materials such as clear, bronze, green, grey and blue-green were considered as per the ASHRAE standards [12]. The window to wall ratio is the ratio of net glass area and gross exterior wall area. The 40% window to wall ratio was maintained for all building models as per ECBC standards. The dimensions of the window are 3.2 m X 2 m. Thermal analysis was carried out by placing various glass windows with and without overhangs in all four orientations (East, West, North and South). The total 320 building models were designed in all four climatic zones of India. Thermal simulations were carried out on peak summer day selected as per the Indian standards. The total solar gain on any exterior surface is a combination of the absorption of direct and diffuse solar radiation given by

$$Q_{so} = a_s.\left(I_B.\cos\theta.\frac{S_s}{S} + I_{sky}.F_{ssky} + I_G.F_{sgrd}\right) \quad (1)$$

Where:

a_s =solar absorptance of the surface

θ =angle of incidence of the sun's rays

S =wall area of the surface

S_s = sunlit area
I_B =Intensity of beam (direct) radiation
I_{sky} =Intensity of sky diffuse radiation
I_G =intensity of ground reflected diffuse radiation
F_{ssky} = angle factor between the surface and the sky
F_{sgrd} = angle factor between the surface and the ground

The total solar gain inside the building through wall, floor, roof is given by

$$Q_{RadSWInAbs}(SurfNum) = QS_{(ZoneNum)} * Abs_{IntSurf}(SurfNum) + A_{ISurf}(SurfNum) * SolarBeamRad \quad (2)$$

where
SurfNum= surface number
ZoneNum =number of zone that surface belongs to
$QS_{(ZoneNum)}$= short-wave diffuse irradiance in the zone [W/m^2]
$Abs_{IntSurf}$(SurfNum)= inside solar absorptance of the surface
A_{ISurf}(SurfNum) = inside beam solar irradiance factor for the surface
SolarBeamRad = outside beam normal solar irradiance [W/m^2]

Interior Diffuse Radiation absorbed by window is

$$QS_{SW} = \sum_{i=1}^{N_{extwin}} T_{BmAll_i} * SunlitFract_i * CosInc_i * Area_i * InOutprojSLFracMult_i - BABS_{Zone} * Beam_{SolarRad} + InitialDifSolDistReflectedW_{(ZoneNum)} + ZoneIntGain_{(ZoneNum)}\%QLTSW + ZoneIntGain_{(ZoneNum)}\%T\_QLTSW \quad (3)$$

$ZoneIntGain_{(ZoneNum)\%QLTSW}$ = short-wave radiation into zone from general (overhead) electric lighting [W]
$ZoneIntGain_{(ZoneNum)\%T\_QLTSW}$ = short-wave radiation into zone from task electric lighting [W]
$QD_{(ZoneNum)}$ = diffuse solar radiation entering or originating in zone [W]

The total solar gain inside the building through window glass surface is given by

$$Q_i = QS_{(ZoneNum)} * Abs_{IntSurf}(SurfNum) + A_{ISurf}(SurfNum) * SolarBeamRad + \sum_{i=1}^{N_{extwin}} T_{BmAll_i} * SunlitFract_i * CosInc_i * Area_i * InOutprojSLFracMult_i - BABS_{Zone} * Beam_{SolarRad} + InitialDifSolDistReflectedW_{(ZoneNum)} + ZoneIntGain_{(ZoneNum)}\%QLTSW + ZoneIntGain_{(ZoneNum)}\%T\_QLTSW \quad (4)$$

where
T_{BmAlli} = beam-to-beam plus beam-to-diffuse transmittance of window
$SunlitFract_i$ = fraction of window irradiated by sun
$CosInc_i$ = cosine of solar incidence angle on window
Area = glazed area of window [m^2]
$InOutProjSLFracMult_i$ = shadowing factor due to inside and outside projections of window frame and/or divider (= 1.0 if there is no frame or divider).
$BABS_{Zone}$ is given by the following sum
$BABS_{Zone}$ = Beam absorbed by opaque inside surfaces + Beam transmitted through the zone's interior windows + + Beam transmitted back out of the zone's exterior windows + Beam absorbed by the zone's exterior and interior windows + Beam absorbed by inside daylighting shelves

The above equations to find the total heat gain inside the building through walls, floor, roof and window glass materials.The climatic regions selected are: Ahmedabad (Hot & dry) with peak summer day May15th, Bangalore (Moderate) with peak summer day April 15th, Calcutta (warm & humid) with peak summer day May 15th and Hyderabad (Composite) with peak summer day, May 15th. Thermal analysis was carried out using Energy plus version 8.1 to compute total heat gain in buildings. Fig. 1 (a) shows building model without shading window, Fig. 1 (b) Shows 0.5m overhang shading window, Fig. 1 (c) Shows 1m overhang shading window and Fig. 1 (d) Shows 1.5m overhang shading window as shown in below. Thermo physical properties of laterite stone were taken from the literature [13]. Table 1. shows the solar thermal properties of different glass materials. These properties are taken as per ASHRAE. Table 2. shows the thermo physical properties of building materials. These properties are as per the Indian standards [14].

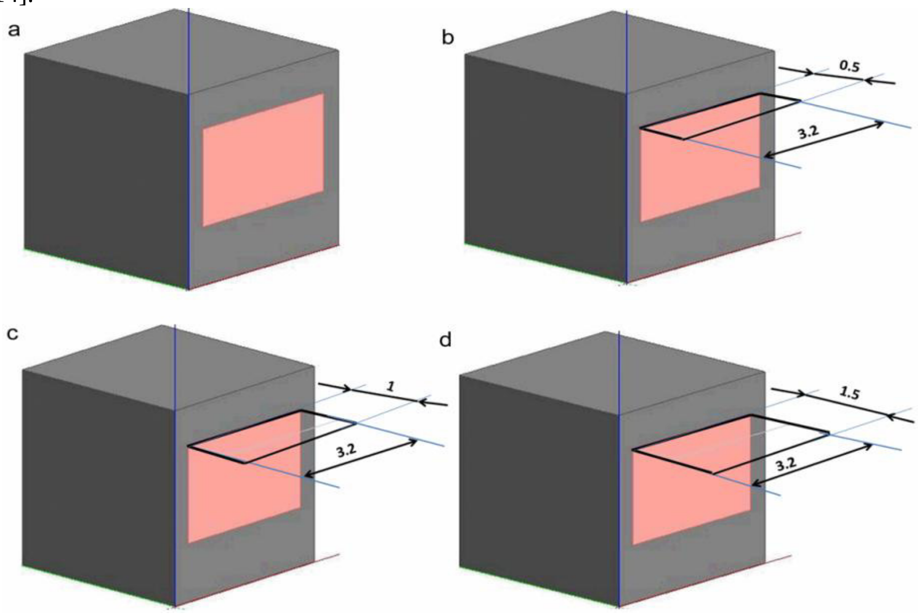

Fig. 1. Building models (a) Without shading window (b) 0.5m Overhang shading window (c) 1m Overhang shading window (d) 1.5m Overhang shading window

Table 1. Solar thermal properties of glass materials

Glass material	Transmittance (τ) (%)	Reflectance (ρ) (%)	Absorptance (α) (%)
Clear glass	76	8	16
Bronze glass	49	5	46
Green glass	47	6	47
Grey glass	46	5	49
Blue green glass	49	6	45

Table 2. Thermo physical properties of building materials.

Building material	Thermal conductivity k (W/mK)	Specific heat C_p (J/kgK)	Density D (kg/m^3)
Laterite	1.3698	1926.1	1000
Reinforced cement concrete	1.58	880	2288
Dense concrete	1.74	880	2410
Cement plaster	0.721	840	1762

3. Results and Discussions

3.1 Heat gain in buildings of Ahmedabad climatic region (Hot & dry):

Fig. 2.(a) to Fig. 2.(d) show total heat gain in buildings of Ahmedabad city (23.07^{0}N, 72.63^{0}E) on peak summer day (May 15th) when 40% window to wall ratio is maintained with different overhang dimensions. From the results, it is noticed that laterite buildings gain less heat in south orientation as compared to the other three orientations. The clear glass window gains 31.52 kWh, bronze glass window gains 29.73 kWh, green glass window gains 29.62 kWh,

grey glass window gains 29.56 kWh and blue green glass window gains 29.77 kWh of heat in building without overhang in south orientation. The clear glass window gains 31.02 kWh, bronze glass window gains 29.45 kWh, green glass window gains 29.34 kWh, grey glass window gains 29.29 kWh and blue green glass window gains 29.48 kWh of heat in building with 0.5 m overhang in south orientation. The clear glass window gains 30.82 kWh, bronze glass window gains 29.32 kWh, green glass window gains 29.18 kWh, grey glass window gains 29.08 kWh and blue green glass window gains 29.36 kWh of heat in building with 1 m overhang in south orientation. The clear glass window gains 30.69 kWh, bronze glass window gains 28.80 kWh, green glass window gains 28.64 kWh, grey glass window gains 28.58 kWh and blue green glass window gains 28.84 kWh of heat in building with 1.5 m overhang in south orientation. From the results it is also observed that laterite buildings with grey glass windows with 1.5 m overhang shading gain the least amount of heat (28.58 kWh) in buildings in south orientation.

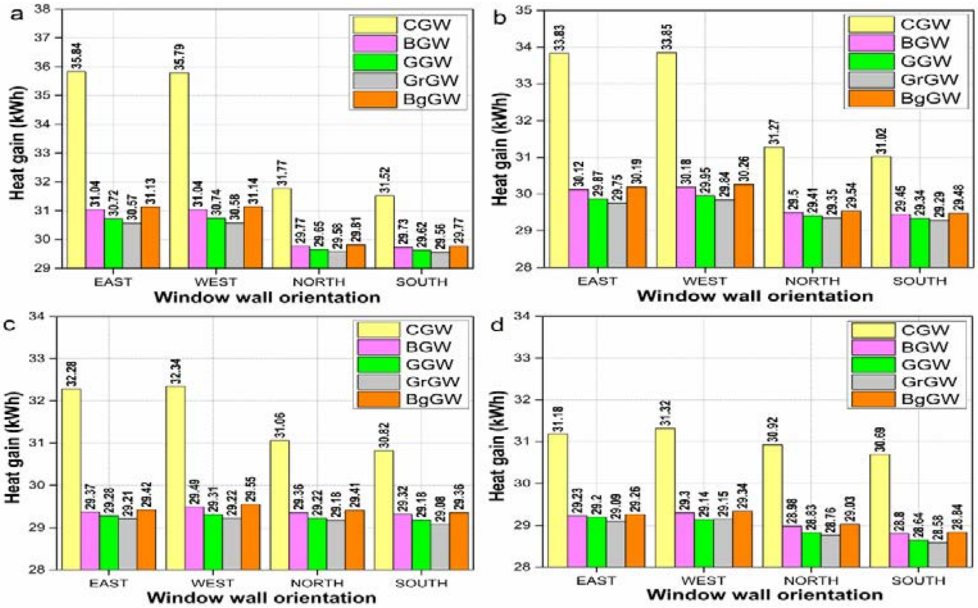

Fig. 2. Heat gain in buildings of the Ahmedabad climatic region (a) Without shading window; (b) 0.5m Overhang shading window; (c) 1m Overhang shading window; (d) 1.5m Overhang shading window.

3.2 Heat gain in buildings of Bangalore climatic region (Moderate):

Fig. 3.(a) to Fig. 3.(d) show total heat gain in buildings of Bangalore city (12.97^{0}N, 77.58^{0}E) on peak summer day (April 15th) when 40% window to wall ratio is maintained with different overhang dimensions. From the results, it is observed that laterite buildings gain less heat in south orientation as compared to the other three orientations. The clear glass window gains 20.11 kWh, bronze glass window gains 18.19 kWh, green glass window gains 18.07 kWh, grey glass window gains 18.01 kWh and blue green glass window gains 18.24 kWh of heat in building without overhang in south orientation. The clear glass window gains 19.54 kWh, bronze glass window gains 17.89 kWh, green glass window gains 17.78 kWh, grey glass window gains 17.73 kWh and blue green glass window gains 17.93 kWh of heat in building with 0.5 m overhang in south orientation. The clear glass window gains 19.29 kWh, bronze glass window gains 17.63 kWh, green glass window gains 17.48 kWh, grey glass window gains 17.41 kWh and blue green glass window gains 17.69 kWh of heat in building with 1 m overhang in south orientation. The clear glass window gains 19.11 kWh, bronze glass window gains 17.30 kWh, green glass window gains 17.16 kWh, grey glass window gains 17.10 kWh and blue green glass window gains 17.33 kWh of heat in building with 1.5 m overhang in south orientation. From the results, it is also observed that laterite buildings with grey glass windows with 1.5 m overhang shading gain the least amount of heat (17.10 kWh) in buildings in south orientation.

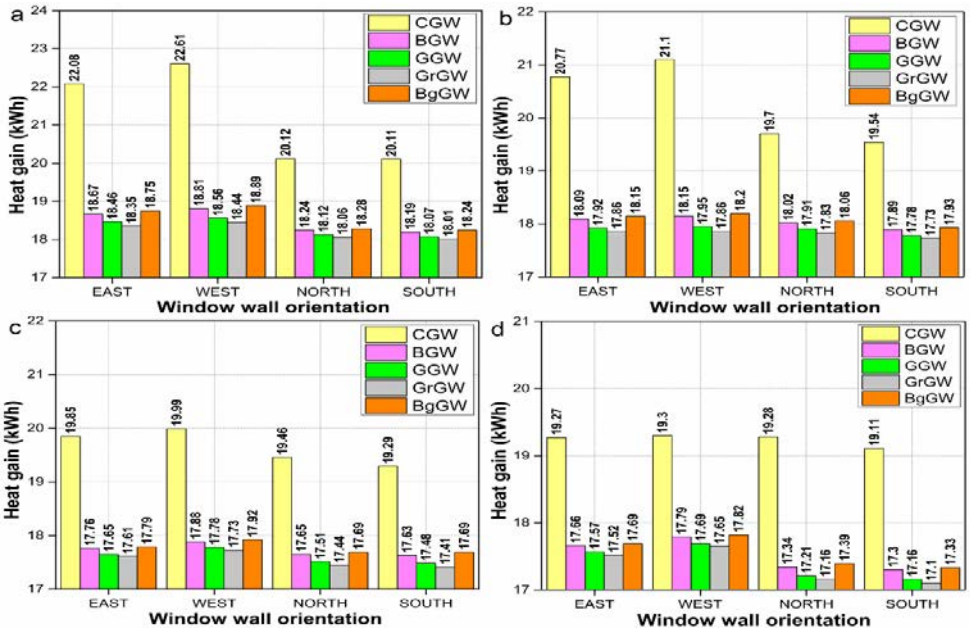

Fig. 3. Heat gain in buildings of the Bangalore climatic region (a) Without shading window; (b) 0.5m Overhang shading window; (c) 1m Overhang shading window; (d) 1.5m Overhang shading window.

3.3 Heat gain in buildings of Calcutta climatic region (Warm & humid):

Fig. 4.(a) to Fig. 4.(d) show total heat gain in buildings of Calcutta city (22.65^0N, 88.45^0E) on peak summer day (May 15^{th}) when 40% window to wall ratio is maintained with different overhang dimensions. From the results, it is clear that laterite buildings gain less heat in south orientation as compared to the other three orientations. The clear glass window gains 40.79 kWh, bronze glass window gains 37.89 kWh, green glass window gains 37.71 kWh, grey glass window gains 37.61 kWh and blue green glass window gains 37.95 kWh of heat in building without overhang in south orientation. The clear glass window gains 40.24 kWh, bronze glass window gains 37.58 kWh, green glass window gains 37.41 kWh, grey glass window gains 37.32 kWh and blue green glass window gains 37.63 kWh of heat in building with 0.5 m overhang in south orientation. The clear glass window gains 40.03 kWh, bronze glass window gains 37.34 kWh, green glass window gains 37.09 kWh, grey glass window gains 36.97 kWh and blue green glass window gains 37.42 kWh of heat in building with 1 m overhang in south orientation. The clear glass window gains 39.88 kWh, bronze glass window gains 36.82 kWh, green glass window gains 36.62 kWh, grey glass window gains 36.50 kWh and blue green glass window gains 36.90 kWh of heat in building with 1.5 m overhang in south orientation. From the results, it is also observed that laterite buildings with grey glass windows with 1.5 m overhang shading gain the least amount of heat (36.50 kWh) in buildings in south orientation.

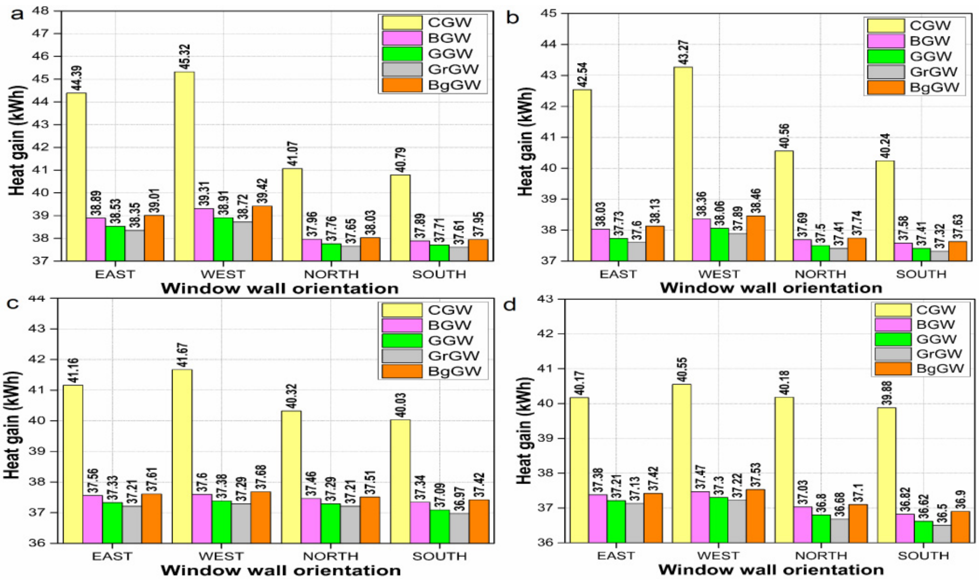

Fig. 4. Heat gain in buildings of the Calcutta climatic region (a) Without shading window (b) 0.5m Overhang shading window (c) 1m Overhang shading window (d) 1.5m Overhang shading window.

3.4 Heat gain in buildings of Hyderabad climatic region (Composite):

Fig. 5.(a) to Fig. 5.(d) show total heat gain in buildings of Hyderabad city (17.45^0 N, 78.47^0E) on peak summer day (May 15th) when 40% window to wall ratio is maintained with different overhang dimensions. From the results, it is obvious that laterite buildings gain less heat in south orientation as compared to the other three orientations. The clear glass window gains 36.13 kWh, bronze glass window gains 34.23 kWh, green glass window gains 34.08 kWh, grey glass window gains 33.99 kWh and blue green glass window gains 34.30 kWh of heat in building without overhang in south orientation. The clear glass window gains 35.84 kWh, bronze glass window gains 33.82 kWh, green glass window gains 33.71 kWh, grey glass window gains 33.63 kWh and blue green glass window gains 33.87 kWh of heat in building with 0.5 m overhang in south orientation. The clear glass window gains 35.64 kWh, bronze glass window gains 33.70 kWh, green glass window gains 33.58 kWh, grey glass window gains 33.51 kWh and blue green glass window gains 33.75 kWh of heat in building with 1 m overhang in south orientation. The clear glass window gains 35.51 kWh, bronze glass window gains 33.53 kWh, green glass window gains 33.36 kWh, grey glass window gains 33.28 kWh and blue green glass window gains 33.57 kWh of heat in building with 1.5 m overhang in south orientation. From the results, it is also observed that laterite buildings with grey glass windows with 1.5 m overhang shading gain the least amount of heat (33.28 kWh) in buildings in south orientation. From the above results it is observed that the heat gain in buildings decreases with the increase in the overhang shading dimensions.

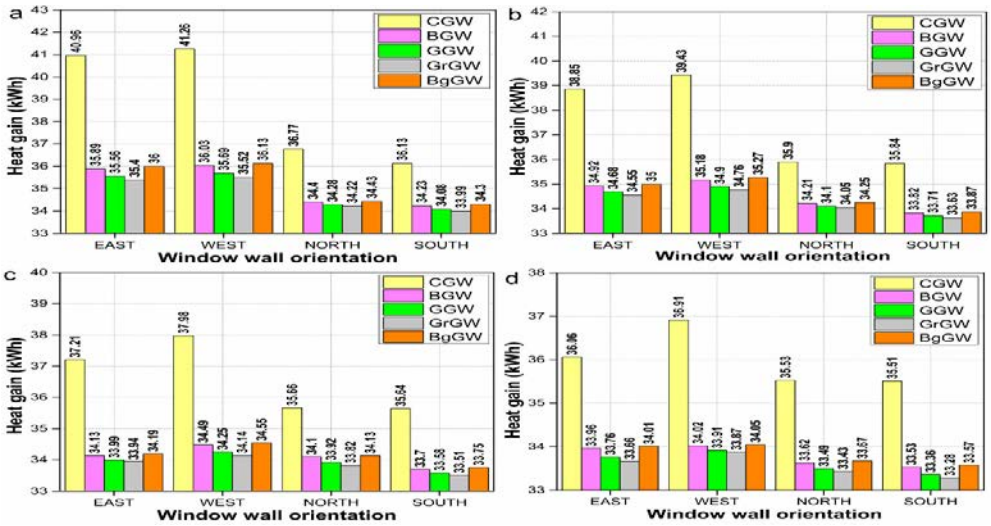

Fig. 5. Heat gain in buildings of the Hyderabad climatic region (a) Without shading window (b) 0.5m Overhang shading window (c) 1m Overhang shading window (d) 1.5m Overhang shading window.

4. Conclusions

The present work presents the significance of various window glass fenestration and overhang shading device dimensions. From the results of the study it can be concluded that heat gain in buildings decreases with the increase in the dimensions of window overhang. The laterite buildings with grey glass window are observed to be the most energy efficient from the least heat gain point of view among buildings with four window glass materials studied. The South orientation is observed to be the best for placing window from low heat gain perspective. The results of the study help in designing energy efficient residential and commercial buildings in four different climatic zones of India.

References

[1] ECBC, Energy Conservation Building Code. Bureau of Energy Efficiency, New Delhi, 2009; India.

[2] Singh I, Bansal NK. Thermal and optical properties of different window systems in India. Int J Ambient Energy 2011; 23(4): 201–211.

[3] Saboor S, Ashok Babu TP. Optimizing the position of insulating materials in flat roofs exposed to sunshine to gain minimum heat into buildings under periodic heat transfer conditions. Environ Sci Pollut Res (online) 2015; http://doi.org/10.1007/s11356-015-5316-7

[4] Mohelnikova J, Hasim A. Evaluation of Optical and Thermal Properties of Window Glazing. Wseas Transactions on Environment and Development. 2009; 86-93.

[5] Kirankumar G, Ashok babu TP. Study of Optimum Inward Glass Tilt Angle for Window Glass in Different Indian Latitudes to Gain Minimum Heat into Buildings. Energy procedia 2015; 79:1039-1045. http://doi.org/10.1016/j.egypro.2015.11.606

[6] Khoukhi M, Maruyama S. Temperature and Heat Flux Distributions through Single and Double Window Glazing Nongray Calculation. Smart Grid and Renewable Energy (online) (2011). doi:10.4236/sgre.2011.21003.

[7] Saboor S, Ashok Babu TP. Effects of air space thickness within the external walls on dynamic thermal behavior of building envelopes for energy efficient building construction. Energy procedia 2015; 79: 766-771. http://doi.org/10.1016/j.egypro.2015.11.564

[8] Ana I, Palmero M, Armando C. and Oliveira Effect of louver shading devices on building energy requirements Appl Energy 2010; 87: 2040-2049.

[9] Ahmed A, Freewan Y. Impact of external shading devices on thermal and day lighting performance of offices in hot climate regions.Sol Energy 2014;102:14-30.

[10] IS 11907 Recommendations for calculation of solar radiation on buildings CED 12: Functional Requirements in Buildings. Bureau of Indian Standards, New Delhi, 1986; India.

[11] Mani A. Solar radiation over India. Allied publishers private limited.1982; India.

[12] ASHRAE Fundamentals of Refrigeration and Air-conditioning, American society of Refrigeration and Air-conditioning. U.S.A. 2001.

[13] Saboor S, Ashok Babu TP. Influence of ambient air relative humidity and temperature on thermal properties and unsteady thermal response characteristics of laterite wall houses. Build Environ 2016; 99: 170-183. http://doi.org/10.1016/j.buildenv.2016.01.030

[14] SP: 41. (S&T) Handbook on functional Requirement of Buildings other than industrial buildings. Bureau of Indian Standards, India, 1987; 33-40.