Effect of Orientation of Window on Building Heat Load: Perspective of N-E India

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Abstract: This paper deals with the change in temperature and radiation penetrating inside the building through window, when window is placed in different orientation. Experiments are performed at NIT Silchar, in building made of wood and one side kept open, fitted with glass. Three different cases are considered south, south-east, and south-west direction are considered. The maximum amount of temperature and heat inside the building is different in different cases. Overall estimation of heat and temperature for Silchar, Assam is being estimated in this paper for different direction. Finally, it is found that maximum heat load for south facing building is observed at 11 am, while for south-east and south-west facing it is found to be at around 1.00 pm. Further, south facing buildings have maximum heat load compared to others.

Keywords: Building's orientation; heat load; temperature; window.

1. Introduction

Buildings are the largest energy consuming sector accounting more than 40% of global primary energy use, producing substantial carbon emissions than other sector in the world [1]. As the concern about the environmental impacts of building is increasing, private and public organizations are progressively requiring the building industry to design and construct buildings with minimal environmental impact [2]. Several studies were conducted about the impact of window design on energy load regarding various factors of windows, to reduce the energy waste by windows [3]. In many countries, the energy required for space heating in buildings makes up the highest share of energy use and represents about 40% of the total energy. However, as the geometry and systems of buildings are getting complicated, more complex studies are needed which analyse the mutual effect of different design factors [4]. As one of the key approaches to low energy design is to invest in the building’s form and enclosure (e.g., windows, walls) [5], many studies treat the influence of enclosures on the energy load. Especially, several studies have been done on the effect of window design on building energy load regarding the factors such as window size, position, glazing properties and orientation. In early studies, one or two factors
were analysed concurrently. In the literature, it is found that the impact of window size was analysed solely [6], and there are several studies were done on window size and position [8-9]. Glazing properties and size along with orientation were also considered together [10-11]. In addition, few precedent articles considered the effect of orientation, size and glazing properties [12-13].

The design parameters, affecting the conservation of energy are; location, orientation, building shape, thermophysical and optical features of the building envelope, size, accommodation type, distance between buildings and natural ventilation arrangement [12]. Assessments on the energy and cost performance of window alternatives revealed that climate, building typology, orientation, transparency ratio and sun control devices impact the energy and cost performance of window systems [13]. However, the research on the influence of orientation of window in a building heat load in NE India is still missing. As North-East (NE) India is still under developing state, this type of detailed and thorough analysis on various window orientation will help the engineers and architects to design their building in the perspective of minimum energy consumption. Therefore, the assessment of the impact of window orientation on a building for the NE region is studied in this paper.

2. Experimental Setup

To fulfil the objective of present work, the experimental setup consists of a wooden building closed by glass on one side which acts as a window for the building. The experimental setup is shown in figure 1. The wooden building has dimensions of $60 \times 60 \times 120 \text{ cm}^3$. All the sides of the wooden building have thermocol of 3 cm thickness incorporated between plywood layers to enhance the thermal insulation. The building has been framed with a glass of thickness of 4 mm with the cross sectional area of $57 \times 118 \text{ cm}^2$. Two parameters have been evaluated to compare the effect of orientation of the window namely the temperature variation with respect to time and the solar radiation intensity. Thermocouple and lux meters have been employed along with the data acquisition system to get the measure of temperature variation and the radiation intensity variation. Four thermocouples have been used inside the wooden building to get the average temperature inside the building. Both the parameters, the temperature and radiation intensity have been recorded inside and outside the building by employing additional thermocouple and lux meter outside the building.

The temperature and heat flux are measured at an interval of 1 hour from 8 am morning to 5 pm evening so that a correct conclusion can be drawn through it. The following day reading with average temperature and heat flux inside the building has been plotted with time at an interval of an hour. The tests are performed at NIT Silchar, Assam, India. Orientation effect of building is evaluated by finding the differences between inside and outside temperature and solar radiation.
3. Results and Discussion

Variation of inside room temperature is plotted against time from 8 am to 5 pm, while the building is facing south (Fig. 2). The highest value of temperature is observed at 12.00 noon, while it is found to decrease thereafter. Indicating a peak heat load at noon. To obtain the effect of orientation, temperature against the time is also plotted keeping the building at south-east and south-west facing (Figs. 3 & 4). It is observed that the temperature increases till 1 pm and thereafter it starts decreasing, indicating shifting of peak heat load requirement at the evening time. Further, it is also seen that deviation of inside and outside temperature is lowest during the building at south facing. This indicate increase in heat loads for south facing buildings. Even though it is sometimes mandatory to build the building in a prefixed direction, however, a great amount of heat load can be reduced by changing the orientation.

Fig.1. Experimental setup

Fig.2. Variation of Temperature while the building is facing south.
Variation of inside heat with time is plotted in Figs. 5-7, for the building facing south, south-east, and south-west direction respectively. It is seen that maximum heat load is in between 10-11 am for the building at south facing, while for south east, the maximum heat load is found in between 11 am to 12 pm. The maximum heat load for south west direction is found nearly at 12 pm. This indicates that requirement of heat load shifted little bit and the energy consumption for south facing would be maximum during 10-11 am while for south east it
would occur at 11 am to 12 pm. Similarly for south west direction, it will be maximum during 12 pm. This variation in heat load is due to the orientation of window in different direction. The heat load decreases at a much faster rate as compare to the temperature drops inside the building, this is due to the fact that temperature is property of the system where as heat is boundary phenomenon. The temperature drops at a slower rate than the heat.

Fig. 5. Variation of Heat with time while building facing south.

Fig. 6. Variation of Heat while building facing south-east.
The plot shown in Fig.8. presents the variation of inside temperature of building (Temp. in) and surrounding temperature (Temp. out) with respect to time from 8 am to 5 pm. Fig.8. shows that with increase of surrounding temperature, the inside temperature of a building increases continuously and reaches its maximum value around 1 pm whereas its heat were maximum during 12 pm. This is because the air molecule present inside the building takes some time to get heat up to such a temperature. The air molecules present inside the building absorbs the heat from the surrounding and radiation present inside the building. The inside temperature of building is too high as compare to surrounding due to its compact shape and radiation falling over it from all direction. The absorptivity of wood with thermacol incorporated with it are not so large but due to continuous radiation falling over it, the temperature inside the building rises up.
4. Conclusion
A preliminary study is performed in the present work to evaluate the effects of orientation of window on the building heat load, keeping the NE India perspective. The orientation of building in the present study is considered in the south, south-east, and south-west direction. Amount of heat load found to increase with time till noon, thereafter starts decreasing. Maximum deviation of temperature for south facing building is obtained at around 12 noon, while for southeast and south-west facing building, it is obtained at around 1 pm. Output of the present study may be extended while making the design of high building in N-E India.

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References
[1] S. William, C. van-Aerschot, C. Kornevall, R. Cowe, D. Bridoux, T. B. Bonnaire, J. Fritz, “Energy efficiency in buildings: Transforming the market, Switzerland”, &World Business Council for Sustainable Development (WBCSD), 2009.
[2] A. Salman, J. Brown, R. Farooqui, “BIM-based sustainability analysis: An evaluation of building performance analysis software”, &Proceedings of the 45th ASC Annual Conference 1, 2009.
[3] R.M.J. Bokel, “The effect of window position and window size on the energy demand for heating, cooling and electric lighting”, &Proceedings: Building Simulation10, 2007, 117–121.
[4] B. Vladimir, “Acquisition of building geometry in the simulation of energy performance”, & Lawrence Berkeley National Laboratory, 2001.
[5] Low-energy building design guidelines: energy-efficient design for new Federal facilities: a guidebook of practical information on designingenergy-efficient Federal buildings, Federal Energy Management Program, U.S. Dept. of Energy, Washington, D.C., 2001.
[6] M.-L. Persson, A. Roos, M. Wall, “Influence of window size on the energy balance of low energy houses”, &Energy and Buildings 38, 2006, 181–188.
[7] A.M. Koohsari, R. Fayaz, B.M. Kari, “The Influence of Window Dimensions and Location on Residential Building Energy Consumption by Integrating Thermal and Lighting Analysis in a Mild and Humid Climate”, &BRIS Journal of Advances in Science and Technology 3, 2015, 187–194.
[8] V.Ž. Leskovar, M. Premrov, “An approach in architectural design of energy-efficient timber buildings with a focus on the optimal glazing size in the south-oriented façade”, &Energy and Buildings 43, 2011, 3410–3418.
[9] V.Ž. Leskovar, M. Premrov, “An approach in architectural design of energy-efficient timber buildings with a focus on the optimal glazing size in the south-oriented façade”, &Energy and Buildings 43, 2011, 3410–3418.
[10] A. Stegou-Sagia, K. Antonopoulos, C. Angelopoulou, G. Kotsiovelos, “The impact of glazing on energy consumption and comfort”, & Energy Conversion and Management 48, 2007, 2844–2852.
[11] N.A.M. Al-Tamimi, S.F.S. Fadzil, W.M.W. Harun, “The Effects of Orientation, Ventilation, and Varied WWR on the Thermal Performance of Residential Rooms in the Tropics”, JSD Journal of Sustainable Development 4, 2011.
[12] K. Hassouneh, A. Alshboul, A. Al-Salaymeh, “Influence of windows on the energy balance of apartment buildings in Amman”, Energy Conversion and Management. 51, 2010, 1583–1591.
[13] L. Vanhoutteghem, G.C.J. Skarning, C.A. Hvid, S. Svendsen, “Impact of façade window design on energy, day lighting and thermal comfort in nearly zero-energy houses”, Energy and Buildings 102, 2015, 149–156.

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