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Investigation of Different Window and Wall Materials for Solar Passive Building Design

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Abstract

The energy consumption associated with the cooling of the buildings is huge. In India buildings consume about 33% of country's power production for cooling and day lighting. The building enclosures such as walls, roofs and glasses play very vital role in reducing cooling loads in the buildings. The proper combination of window glass materials and wall materials can cut down the cooling costs extensively. In the present work, five different glass materials such as clear, bronze, grey, green and blue-green glass materials were selected and four different building materials such as burnt brick, cinder concrete, dense concrete and fly ash brick either side plastered with cement plaster were selected. Total twenty building models with various combinations of window glass and wall materials were designed in licensed Design builder 4.3.0.039 version and thermal analysis was carried out in Energy plus 8.1 software package. Thermal performance of various building models in four different climatic zones such as hot and dry, temperate, warm and humid and composite were investigated. From the results of the study, it is observed that fly ash brick wall building model with grey window glass is found to be energy efficient in all Indian climatic zones from the reduced cooling load point of view among all studied combinations in East, West, North and South orientations. From the results it is observed that the fly ash brick buildings with grey glass window is observed to be the most energy efficient combination for reducing cooling loads as they gain the least heat gain in south orientation (21.51 kWh) for Ahmedabad region. The results of the study help in designing energy efficient passive buildings.

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Keywords: Passive buildings; Green buildings; Building heat transfer; Energy efficient materials.

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1. Introduction:

Buildings are responsible for about 40% of total energy use in the world and they also account for more than 40% of the global carbon dioxide emissions. With the recent boom in the construction sector, there has been a sudden increase in energy consumption, especially in countries like India. Buildings are consuming 33% energy in India. In that 8% of energy is consumed by commercial buildings and 25% of energy is consumed by the residential sector [1]. India has substantial climatic variations from region to region. Passive building design is the most important factor in ensuring energy efficiency in buildings. Buildings with passive design can consume around 10% - 15% less energy as compared to conventional buildings without incurring any incremental cost [2]. Thus, it is necessary to focus on the vital aspect of energy efficiency at the design stage of the building itself. Previously, a study has been carried out on numerical computation of window design to reduce radiation in buildings using clear and brown glass window materials [3]. Thermal requirement of maximum window to wall ratio was studied earlier [4]. Optimization studies of the insulation location inside the flat roof were reported in the literature [5]. The evaluation of thermal and optical properties was studied earlier [6]. Impact of window to wall ratio on life cycle environment was presented in the literature [7]. Thermal response of laterite buildings was reported in literature [8].

The present work presents the thermal performance of buildings built with different combinations of window glass and building wall materials to recognize the energy efficient combination of window and wall materials in different climatic regions of India.

2. Methodology

The building models with dimensions 3.5 m X 3.5 m X 3.5 m were designed in Design builder. The thickness of the wall is 0.2 m plastered either side with 0.015 m cement plaster each side. Fig. 1. (a) shows the dimensions of a building model and Fig. 1. (b) shows the building model with 30% window to wall ratio. The window to wall ratio is the ratio of vertical fenestration area to the gross external wall area. The window to wall ratio for the building models taken is 30% as per the ECBC. The dimensions of the window are 2 m X 1.8375 m for 30% window to wall ratio. The roof material used is reinforced cement concrete of 0.15 m plastered either side by 0.015 m cement plaster each side. For floor, dense concrete was used. The roof and floor materials are same for the all building models studied. Fig. 2. shows the images of the wall materials used in the study. The wall materials used for the study are burnt brick, cinder concrete, dense concrete and fly ash bricks. Reinforced cement concrete is used as the roofing material. Thermo-physical properties of the wall materials are considered as per the Indian standards [9]. Table 1. shows thermo-physical properties of wall materials. Thermal properties of fly ash brick are taken from the literature [10]. The window glass materials used for the study are clear, bronze, grey, green and blue-green glasses. The solar thermal properties of five glass materials are taken as per the ASHRAE standards [11]. Table 2. Shows the solar thermal properties of the window glass materials used in the study. After designing, building models with all the combinations of wall and window glass materials, thermal analysis was carried out in Energy plus software package at four different climatic conditions of India. The major city is considered in each climatic zone of India for the analysis purpose. The four climatic zones of India are hot and dry (Ahmedabad 23.07^{o} N, 72.63^{o}E), temperate (Bangalore 12.97^{o}N, 77.58^{o}E) warm and humid (Bombay 19.12^{o}N, 72.85^{o}E) and composite (New Delhi 28.57^{o}N, 77.12^{o}E). The window is located in different orientations each time such as East, West, North and South. The heat gain through the roof, walls and windows were noted in different climatic zones with different combinations of wall and window materials to recognize the best location of the window (East, West, North and South) and the best combination of wall and window materials. Thermal analysis was carried out on the peak summer day of the cities considered for the study. In Ahmedabad the peak summer day is May 15th, in Bangalore the peak summer day is April 15th, in Bombay the peak summer day is May 15th and in New Delhi the peak summer day is June 21st as per the Indian standards [12].