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ORIGINAL ARTICLE

Daylighting and energy performance of a building for composite climate: An experimental study

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Abstract The present study includes overall energy saving through thermal as well as daylighting for composite climate for the building known as SODHA BERS COMPLEX (SBC) situated at Varanasi, India. The building has been designed including all the passive concepts for thermal comfort as well daylighting to maximize the use of natural lighting for the occupants in day to day activities. This approach can be useful for multi-story building for rural and urban areas for both residential and commercial buildings. The energy saving potential and corresponding CO_2 mitigation have been determined for different lifetimes of the building. The energy matrices namely energy payback time (EPBT), energy production factor (EPF) and life cycle conversion efficiency (LCCE) of the building have also been estimated by considering overall energy saving. An annual energy saving has been obtained as 3675.61 kW h due to daylight concept by considering different Zones in each floors of the building. Further, the EPBT has been determined as 49.25 years and 34.73 years for average 4 °C and 6 °C temperature difference between ambient and room, respectively. It has been found that when thermal heat gain increases in the building LCCE and EPF increase.

1. Introduction

The energy is the integral part of the human life for almost all activities e.g. industrial, domestic, medical, transport. The world is facing a grim situation such as depletion of fossil fuel reserves, global warming and other environmental concerns, geopolitical and military conflicts and continuing fuel price rise if continuing the use of conventional energy sources [1–3].

Building of future has to take into account the tasks and the opportunities brought about by, environmental, societal and technological changes [4]. Energy saving can be done not by bringing down the standard of living, but by utilizing more efficient technologies to produce the similar, or higher, levels of comfort and convenience, we have come to enjoy and appreciate [5]. Due to the environment and sustainable development issues, governments have increased their focus on energy saving technologies in the building and other sectors. For the commercial and residential building evaluation of energy efficiency is difficult to describe with precision as there is often a lot of vague information and various types of inaccurate assessment of data. The evaluation of energy saving in the building design selection has uncertainty and complexity. To select a suitable design, one needs to consider the use of function, technology, economics, and many other factors. The energy saving through the daylighting opening in the building

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Nomenclature

A_f	floor area (m^2) of the room	EPBT	energy payback time (years)
CW	clerestory window	EPF	energy production factor
E_{in}	embodied energy (kW h)	SBC	SODHA BERS COMPLEX
E_{sol}	annual solar radiation (kW h/m^2)	T_{LB}	lifetime of the building (years)
E_{aout}	total annual energy saving (kW h)	LCCE	life cycle conversion efficiency
I_g	global solar radiation (W/m^2)	LW	light well

is not only easy for quantitative calculation of the indicators, but also for qualitative description [6,7]. The energy efficient building design selection at the present time depends on the selector's awareness about energy crisis and experience. In buildings, lighting systems are responsible for consuming large amount of energy all around the world [8,9]. Nowadays significant energy can be saved by creating cost-effective efficiency developments in the buildings and their equipment – which will reduce any nation's energy consumption and GHG emissions which lead to significant economic savings to consumers [4]. It is reported that in the commercial sector around 25% of the total electricity is consumed by lighting systems [10,11]. The range of energy consumption varies greatly from country to country and is not only due to design and climatic conditions, but also to cultural habits. In USA, the lighting end-use in commercial building is 39% [11]; in the China, 15% [8]; in the Netherlands, 55% [11]; and in India more than 20% [12]; and in the UK it ranges from 30% to 60% [13]. Bansal and Minke (1988) has concluded that conventional energy resources are being exhausted through its limited resource and uncontrolled harnessing. To meet the energy requirements the world heavily relies on fossil fuels [14]. Almost 80% of the global energy demand is met by fossil fuels such as oil, gas and coal [15]. Presently renewable energy and nuclear power are contributing 13.5% and 6.5%, respectively of the total energy needs in the world. The enormous amount of energy being consumed across the world has led to adverse effects on the ecosystem of the planet [16].

According to recent studies, natural light not only improves students test score but also provides better physical health. Human beings also prefer to work in daylighting. It is an important component of the passive building. The interior of the buildings can be illuminated in several ways such as window, light well, clerestory [17], the laser cut penal [18], light shelf, light pipes [19,20], anidolic light-duct [21]. The use of the all these daylighting systems can save the artificial lighting in the buildings. These provisions are equipped to maintain coincidence to human visual response, attractive indoor environment, and allow people to maintain visual contact with the outside world [22–28]. Daylighting concept in building is an effective option of saving fossil fuels which ultimately leads to saving substantial amount of money and reducing emission of greenhouse gases [17].

In the present study, the complete energy and economics analysis has been determined by considering both thermal and daylighting concepts for the whole building, which is divided into different Zones in each floors. This paper presents monthly daylight performance of the building based on hourly measured illuminance data under clear sky conditions. The paper evaluates the lighting energy saving and CO_2 mitigation of the building. Further, the three energy matrices namely life cycle conversion efficiency (LCCE), energy payback time (EPBT), and energy production factor (EPF) of the building have also been determined by considering energy saving due to both thermal heat gain and daylighting. The embodied energy of the whole material has been taken to determine the energy matrices of the building.

2. Background information

The building featured is located at Varanasi, Uttar Pradesh, India (latitude 25.28°N, longitude 82.95°E and altitude 76.8 m). It is four-storey building.

2.1. Building geometry

The building was designed with wall windows, clerestory windows and light well, with the provision of natural ventilation through environmental conservation measures and sufficient daylight. Fig. 1a shows the photograph of the building. The SODHA BERS COMPLEX (SBC) has been built on land area of 236.91 m^2. The covered area of the each floor is 152.42 m^2 of the SBC. Each floor of the building is divided into three Zones. The brief discussion of basement, ground floor, first and second floor has been given in coming sections.

2.1.1. Basement

Fig. 1b shows the top view of the basement which is made by using earth shelter concept for cooling and daylighting. For evaluation of energy saving, it is divided into three Zones. The daylighting and natural ventilation is provided by clerestory window and rooftop window through light well (LW304) which is located on the top of east (Zone 3) and south (Zone 1) for the basement, respectively. In the Zone 2 of the basement there is no special provision to provide daylight; this Zone illuminates through clerestory window and rooftop window. It is commonly used for community services.

2.1.2. Ground floor

Fig. 1c shows the top view of the ground floor plan. It has facility of two light well in addition to sufficient cross-ventilation from north to south direction due to unique naturally made wind channel from east being a dead end of the road to cool the rest of whole building. The Zones 1–3 of the ground floor illuminate through east wall opening, light