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Influence of natural and artificial light on structured steel buildings

E.C. Castanheira [a,*], H.A. Souza [a], M.Z. Fortes [b]

[a] Department of Civil Engineering – Ouro Preto Federal University(UFOP), Brazil
[b] Department of Electrical Engineering (TEE) – Fluminense Federal University (UFF), Niterói, RJ, Morro do Cruzeiro Campi Ouro Preto Minas Gerais 35400-000, Brazil

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ABSTRACT

Optimum possible use of natural light is a factor that must be considered in new construction projects. Particularly, construction structuralized in steel needs research that supports the designers in devising proposals. In this work, the author considers references for lighting projects for construction structuralized in steel, using a methodology built from the compilation of several variables that directly interfere in the development of architectural projects both in residential, commercial and/or services buildings. It takes into account the use of all natural light potential and new lamp technologies, which confronts the demands of energy economy that surround the subject of energy consumption reduction in construction focused on environmental sustainability. Some points related to the integration between lighting and architectural projects also are mentioned. To conclude this work, two project guidelines (methodological approaches) for support in the delineation of projects are presented considering three distinct and interconnected approaches: environmental, normative and architectural. The guidelines for the proposals attempt to efficiently handle diverse design aspects that can contribute to more adequate solutions in all sectors that involve creating projects and, executing them. Thinking about the project from a systematic point of view taking into account the contribution of each sector improves project quality.

Contents

1. Introduction

Buildings account for nearly 40% of global energy consumption and 40% and 15% of that are consumed, respectively, by heating, ventilation and air conditioning (HVAC) and lighting [1]. The use of energy in commercial buildings, for example, is declined, reaching 250 kW h/m^2 in 2002.[2].

To know the relation between technologies of light bulbs well, the potential of the natural light and lighting is the initial point so that a lighting project is adjusted to the building's use. The subject of lamps and lighting with revision of the characteristics of some lighting equipment technologies (in special lamps) available on the market is presented in Damelincourt [3]. The impact of the application of electronic lamps in

* Corresponding author.
E-mail addresses: eduardocunhacastanheira@gmail.com (E.C. Castanheira), henorster@gmail.com (H.A. Souza), mzf@vm.uff.br (M.Z. Fortes).

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buildings is a concern, with considerations regarding product quality. In Fortes et al. [4–6], the authors study compact fluorescent lamps (FLC) available on the Brazilian market tested by a laboratory certifier and the harmonic impacts.

In Brazil, where this work was developed, efficient lighting system projects have begun replacing old projects, a process known as retrofitting, which is argued in detail in Vahl et al. [7] considering technician, economic, and environmental aspects in the project analysis.

The impact of technology in energy building consumption also must be studied when making lighting equipment choices. When commencing a project, an analysis of the lighting and energy efficiency index must be conducted. In Stroker [8], some of these indices are described. Evaluating with good precision the consumption that the construction will have is part of the planning for an efficient and adjusted project; in this context, Stokes et al. [9] present a proposal for evaluation of domestic lighting demand.

The use of control systems and automation in buildings (Building Automation and Control Systems, BACS) and the ecodesign for lighting projects to personalize the environments is also foci of the analysis in the consumption criteria and reuse of natural light. The use of index LENI (Lighting Energy Numeric Indicator) that it is developed in this concept is debated in Parise and Martirano [10]. Another work focused in the control systems with potential analysis of lighting energy savings in office rooms is presented in Roisin et al. [11]. In studies with a focus on reducing consumption in residential sector can highlight the review presented in Pacheco et. al. [12] and Gago et al. [13].

Moreover, Parise and Martirano [14] present a criterion to evaluate the yearly daylight impact on energy performance of internal lighting according to daylight availability. This research team presents the suggestion of a lighting systems certificate involving some specific performance indicators [15].

It is also had that to highlight several research studies related to building certifications. In Brazil, in particular, there is a labeling program for buildings, supervised by the Ministry of Energy, through the Program for Energy Conservation (PROCEL) and the Brazilian Labeling Program (PBE) [16,17]. Worldwide, there are programs with the same focus, and Marshall et al. [18] offer a review of definitions and calculation methodologies. Melo et al. [19] compare the standardization of Brazilian buildings and ASHRAE Standard 90.1 [20] and summarize the equivalence between the standards.

Other interesting researches related to buildings' energy consumption highlighted by the authors of this paper are as follows: influence of the coupling between daylight and artificial lighting on thermal loads [21], an overview about energy building consumption with respect to different building types [22], effects of occupancy and lighting use patterns [23], strategies to reduce energy use for lighting [24], neural network models used in lighting control of LED systems [25] and economic analysis of the daylight-linked on/off lighting control system installed in office buildings considering different numbers of floors and glazing ratio [26].

This paper addresses the main aspects of natural and artificial building lighting design, with special attention given to structured steel buildings and general requirements for energy efficiency and comfort with reduced environmental impact. In this context, guidelines are proposed that encompass three approaches: environmental, architectural and normative aspects. The approaches were compiled from studies, checks, standards and practice of architecture projects development, where these various topics are often considered in the project design.

2. Natural lighting and energy efficiency

The main factors influencing the energy efficient use of natural lighting in buildings are the aspects related to the environmental characteristics: knowledge of local area climatic characteristics, the type of building, daylighting strategies (opening solutions incorporated in the building), and types of shading systems and their control strategies. [27] reported that daylighting controls can result in energy savings ranging from 30% to 77%.

2.1. Climate characteristics

One of the main constraints aspects of comfort and energy efficiency in buildings is, of course, the prevailing climate. The natural lighting available in a given location is a function of local latitude, the prevailing weather conditions (particularly the cloudiness of the sky), and the time of day and year. The diverse climates usually have two more seasons to solve complicated thermal conditions and two intermediate periods that have relatively mild conditions most of the time. Brazil's seasons are characterized by a high availability of natural light. These characteristics give the country good potential conditions for the use of natural light throughout the year for illumination of interior spaces; however, this can also leads to the situations of potential thermal discomfort, especially in tropical countries, which imply the need for effective sun protection strategies. It is important to consider the climatic characteristics in the choice of materials for the building. The paper [28] presents these materials assessment in an analysis of the building internal temperature.

2.2. Building types

Buildings with higher electricity consumption for lighting have periods of operation that coincide with periods of increased availability of natural light. Practically, all non-residential buildings have significant potential savings in electricity for lighting if investments are made in effectively utilizing natural lighting.

To know and explore the use of natural lighting in new projects or adaptations in existing buildings is also part of the challenges. Some interesting case studies presented in Ref. [29] where a historic building was adapted in the natural light concept use for activities as public library and [30] where computational simulation support lighting analyzes in a Palace.

2.3. Daylighting strategies

Among the various fields of environmental comfort and energy efficiency in buildings, natural lighting has higher level relationships and interdependencies with architectural design. The shape, dimensions, and other architectural features of buildings (and particularly those directly related to glazed areas) are the first factor that influence the use of natural light, while defining the image of the building, both from an esthetic, functional and technological point of view. There is, therefore, interest in properly articulating these two aspects from the earliest stages of a project, with the fundamental assumption functionality and the guarantee of good natural lighting inside the various sections of the building. The need to provide the most appropriate lighting levels is a necessary condition, but still insufficient, since there is still a need to ensure the safety and well-being of the occupants, i.e., enjoying a comfortable indoor visual environment and visual contact with the outside, absence of glare, energy efficiency, among others aspects.

2.4. Shading systems and their control strategies

It is very significant to influence the effect that shading devices may have on lighting conditions, visual and thermal comfort, and energy consumption (for artificial lighting and air conditioning, for example) in buildings. Shading devices can play several following functions, such as:

- Protection against sunlight.