Daylighting, Wellbeing and Health for Industrial Employees

MAÍRA VIEIRA DIAS[1], PAULO SERGIO SCARAZZATO[1]

[1]School of Civil Engineering, Architecture and Urban Design, University of Campinas/UNICAMP, Campinas, Brazil

ABSTRACT: Although in recent years the interest for daylighting in buildings has experienced a notable growth in developed countries, the same is not true in some emerging countries. There is a lack of studies and recommendations for some typology of buildings, such as industrial buildings in Brazil, especially regarded to the employee's health. Even these buildings having windows and other daylighting devices, its daylighting is poor due to undersizing or even lack of maintenance. Thus, the most common way to obtaining an adequate amount of lighting in such buildings is through artificial lighting systems with uniform general illumination, despite the great availability of daylight. The demand for lighting is still influenced by the amount to be provided for spaces and specifics tasks according consecrated standards that do not consider light quality and visual claims of the employees. However, light quality is extremely important because it is closely related to productivity, health and security of employees. This paper discusses the inclusion of daylighting in industrial design process as well in standards concerning that building typology that consider the wellbeing and health of the employees.
Keywords: daylighting, industrial building, light quality, wellbeing, health.

INTRODUCTION

In an industry, better performance of human and physical resources can be achieved with a design that takes into account not only the functionality and specificity of the task to be developed, but also the environmental conditions [1, 2].

Studies have shown that the productivity and task performance have a close relationship with the working environment and the lighting system [1, 2]. The influence of lighting levels in productivity was subject of several investigations throughout the last 100 years, however, few studies have been well documented [1, 3, 4].

The research named *"Mechanisms involved in enhancing human performance by changing the lighting in the industrial workplace"* [5] showed that there are at least 10 mechanisms that contribute with the increase of human performance through lighting improvement: visual performance, visual comfort, visual ambience, interpersonal relationships, biological clock, stimulation, job satisfaction, troubleshooting, halo effect and changing process.

Most part of industries are characterized by large spaces, where even in the presence of windows, the amount of daylighting they offer is limited. Thus, the most common form to provide a lighted environment is through artificial light systems with uniform general lighting. The task illumination in most cases is only used for special activities and this lighting is not adjustable. Many researches related with lighting quality, performance, users preference and perception, levels of glare and its interference in visual field are realized in other buildings typology, but not for the industrial ones [6, 7]. Despite it employs a considerable amount of people, in Brazil, this segment still lacks such studies, unlike what is happening in Europe.

Although the Brazilian Association of Technical Standards (ABNT) presents some guidelines for lighting in some areas of industrial environment, there is no standard, legislation or specific and appropriate code for lighting for such building typology in the country yet.

The research *"Daylighting in Manufacturing Sectors of Industrial Buildings. Case Studies in the Metropolitan Region of Campinas"* [8] diagnosed that industrial lighting generally was designed to meet the minimum required by NBR 5413: Interior Illuminance [9], prevailing at the time. The lighting design aimed cost savings, but didn't considered health, wellbeing, performance and safety of users. There is recurring concern related with the amount of light, without its quality is also taken into account.

However, to understand the relationship between lighting and work, first is necessary to identify how the lighting can affect the visual performance: through the visual system, the circadian system and the perceptive system [10].

The visual system stimulations can be described by five parameters, namely: visual size, luminance contrast, color difference, quality of the retinal image and illuminances. These parameters are equally important on determining the extension from which the visual system can detect and identify these stimulations. As to the circadian system, our knowledge about its interaction

with the lighting conditions and how this can affect the human performance has grown rapidly in recent years. However, approaches related with perceptual system still have received little attention by researchers [10]. More attention should be focused on visual discomfort, which can change the employees' mood and motivation, mainly in extensive works. Lighting conditions that achieve a high level of visual performance hardly will be considered uncomfortable [1, 5, 10].

Studies in industrial environments showed that employees presents themselves, in most part, highly dissatisfied with their working environment, although the measurements have shown that lighting levels are in conformation with the standards [1]. Lighting should allow the visual system to extract information from the visual environment and, in this sense, an examination of the causes of visual discomfort should start with the consideration of visual environment aspects which are linked with the ability of extracting information [10]. The lighting effect in task performance depends on task structure and the visual component of where it occurs. Tasks witch visual component is larger will be more sensitive to changes in lighting conditions with the tasks where the visual component is inferior [10].

PURPOSE

To discuss the inclusion of daylighting in industrial design process as well in standards concerning that building typology; consider the wellbeing and health of the employees.

METHODOLOGY

The research presents two main steps: (1) data collection and choice of the industries in the Metropolitan Region of Campinas, Brazil and; (2) qualitative evaluation of daylighting systems.

From the forty industries selected according with size and lighting systems applied, four units - where three of them are multinationals installed in the country - were chosen for the research development and these will be identified by the alphabet letters.

The data collection of the daylight and artificial lighting systems was made, through a field form [11] for diagnosing the main aspects of environment, as the surface materials, colors, lamps and luminaries (type, quantity, potency, maintenance, lighting strategy and light distribution, among others).

The qualitative evaluation of the light distribution was performed by High Dynamic Range (HDR) images, with the Sony Cyber-Shot DSC-S730 camera calibrated [12, 13]. The pictures were shot with it supported by a Greika WT 3770 trivet and the ranges of exposure values (EV) taken varied from -2 to +2, with intervals of 1.0. The photographed images were overlapped in the Picturenaut software [14] to create the HDR image, which was processed in the RadDisplay [15] to obtain its correspondent in false colors (FC). The RadDisplay [15] also allowed the luminance assess at the chosen points.

Computer simulations were performed through the DIALux software [16] - validated in accordance with the standard CIE 171:2006 Test Cases to Assess the Accuracy of Lighting Computer Programs [17] - and the ceiling, walls and floors reflectance were fixed according with the existing case studies. These simulations were made for the time in which the HDR images were collected, in order to compare with the results of them. The chosen sky conditions were clear sky, for being the same condition of the visits dates.

RESULTS

In general, all four industries showed a good light distribution, however some situations are recurrent.

In all the case studies were verified the use of dark colors on the surfaces, mainly on the ceiling. However, the use of lighter colors would offer greater reflection of light and more brightness sensation in the environment.

Another situation that was found was the lack of integration between the equipment's layout and the lighting system, most notably verified in Industry C (Fig. 1).

Figure 1: HDR image in Industry C - lack of integration between the equipment's layout and the lighting system.

In Industry A was observed the lack of integration between the natural and artificial lighting systems.

Despite the artificial lighting has parallel actuation from the windows, it remains turned on during all the operation time of the company, independently of daylight being enough or not to give the environment quality lighting (Fig. 2).

Figure 2: HDR image in Industry A - lack of integration between lighting systems.

In Industries B and C task illumination has higher levels of luminance and, for being installed on a height closer to the workers' visual field, commits their visibility, performance and security (Fig. 3).

Figure 3: HDR image in Industry B - task illumination installed on a height closer to the workers' visual field.

Regarding the maintenance of daylight capturing systems, Industry B is the one that presents the most critical situation, due to the large amount of particles that are deposited on the sheds. If proper maintenance is made, more quantity of light would be transmitted to the indoor environment and this can, therefore, contribute with the reducing use of task lighting (Fig. 4).

Figure 4: HDR image in Industry B - lack of maintenance of daylight capturing systems.

Industry D presented the best lighting conditions as natural light available, since the zenithal presented proper maintenance, the artificial lighting system is only triggered at the end of the day or when it's needed, and there is employees education and training about the importance of the use of natural resources and energy efficiency (Fig. 5).

Figure 5: HDR image in Industry D - daylighting conditions.

CONCLUSION

Since the end of the nineteenth century some environmental aspects have been incorporated from industrial architecture from England and European countries were adopted in industrial buildings in Brazil, e.g. the use of sheds and windows throughout the facade, to supply the space with adequate daylighting.

However, even though these solutions have been incorporated, in the past, by cultures of both industrial and construction professionals, we note that despite the gradual involvement of the architect in industrial design development, such knowledge were either abandoned or, worse, forgotten.

In Brazil, the matter of the architecture of industrial buildings is not totally incorporated in the minds of most business and industrials people yet; who adopt the "rational" design for this typology, as a rapid response for production needs. The designs are not dictated by environmental conditions and become more common buildings that have problems related with environmental comfort, creating poor working conditions to their employees.

Regarding the use of daylightinhg, we realize that there is still widespread unknowledge about this subject and techniques to be adopted. However this research allowed to verify the current performance of lighting systems and their potential for exploitation and showed that the introduction of minimal care can contribute to improve the work environment in terms of lighting. This fact helps developing guidelines that should be considered in lighting design conceptions, favoring the dissemination of the importance of studies in this building typology.

The analysis revealed lack of integration of lighting design, both natural and artificial, with the layout of production sectors. This situation aid glare problems, due light incidence on the equipments surface used in production line, compromising the employees' visual system in their workstation, damaging their visibility and task performance, which still may lead to error situations and therefore accidents.

Problems related with luminaries used have also been found, since they are not efficient and compromise the efficiency of the system. There is still lack of awareness by the industrials and employees with luminaries triggered at times when the availability of daylight is enough to cover the environment with adequate lighting levels.

Regarding the maintenance of lighting systems, many problems were diagnosed. The lack of maintenance is common, where the daylight capturing systems have accumulation of particles, compromising the passage and uniform light distribution in the space, and generate shadow areas. In industries where systems showed no accumulation of particles, this fact was due to the recent change of systems' elements. None of the analyzed industries have in their design technical platform on the roof so that proper maintenance can be performed.

In relation to the architecture of the buildings, consistent strategies with the type of environment still needs to be developed, as the internal surfaces are not handled with care, not aiming at efficiency of lighting systems, since interferes on the ambient light feeling and the absorption and reflection of light.

The industrial design should consider the fluxes and production process targeting the appropriate integration of systems. The workstations should be arranged properly so that the daylighting system adopted can be sized and located aiming its efficiency and not contribute with the incidence of glare. Techniques platforms for systems' maintenance for light capture in the roof should be incorporated into the project, so their cleaning occurs without interfering in the production process.

Also according with the process, the architect should choose which is the best daylighting system to be used, as well as their materials. In places where the production process generates particles or fats should be avoided, in the openings, the use of materials that cause greater adherence.

Therefore, the daylighting design does not imply simply on choosing a particular system and use it on a building construction, but going further. The design requires studies and its methodology should have communication between multidisciplinary teams, so that there is integration between the different systems (lighting, structural, mechanical, etc.), the indoor space and surroundings. We need to have in mind not only how to equip lighting environments, but what will be the effect of lighting and what quantity and quality desired.

The illuminance levels required are fundamental in any project where the performance of the visual task is an integral part of the activities to be developed in the environment, but the project decisions can lead to different lighting recommendations. What should be discussed and understood is "how much light is necessary to the vision?", "how well can we see?", "how much light is needed to provide a safe and productive environment?" But, beyond the amount of light we have to consider the quality of the same, which is related with subjective factors that create a comfortable environment. Thus, the use of daylighting in projects is essential and it becomes necessary to acquire awareness of its importance and magnitude.

Issues related with quality of lighting related with health and wellbeing of users of a given environment has increasingly gaining prominence, although normative instruments are still scarce on the theme. As lighting can ease or restrict human actions in workspace, this research is having a deployment in the study *"Lighting*

in industrial environment and its influence on employee's visual field", where it will be investigated in a multinational presented here (Industry A), the quantity of light that reaches the employee's eyes in his workspace and how this light affects his visual system.

Note that after the present study, the Industry A changed its artificial lighting system towards a greater energy efficiency and works are being carried out in the unit to provide a better working environment for its employees.

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