Integrated lighting system for an office space in the tropics of Costa Rica

Sistema de iluminación integrada para espacios de oficina en el trópico de Costa Rica

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Keywords

Control devices; daylight; sustainability; energy saving; glare.

Abstract

Today, thanks to advances in research and technological development, natural and artificial light is concerned with the visual well-being of man and the search for the ideal lighting conditions, which guarantee optimal development in their daily tasks. Through the descriptive methodology, it was proposed that despite the advances and continuous efforts to innovate in technology that refers to the control and redirection of natural lighting, there are still paths to explore, since in many cases, These advances have guaranteed great savings in energy consumption but not in the visual satisfaction of its users. Hypotheses were formulated in the search for the use of different control devices and redirection of sunlight inside office spaces, which allows office users to control glare, which is the main problem present in the climate tropical. This research concluded that although explorations have already been carried out on the subject, a theoretical-experimental work would represent one more contribution to the daily task of research to improve knowledge about the control of natural lighting in tropical climate countries.

Palabras clave

Elementos de control solar; luz natural; sostenibilidad; ahorro energético; deslumbramiento.

Resumen

Hoy en día gracias a los avances en la investigación y al desarrollo tecnológico le concierne a la luz natural y artificial el bienestar visual del hombre y la búsqueda de las condiciones lumínicas idóneas, que garanticen el óptimo desarrollo en sus tareas cotidianas. Por medio de la metodología descriptiva, se planteó como a pesar de los avances y los continuos esfuerzos por innovar en la tecnología que se refiere al control y re-direccionamiento de la iluminación natural, aún existen caminos por explorar, ya que en muchos casos, estos avances han garantizado un gran ahorro en el consumo de energía pero no en la satisfacción visual de sus usuarios. Se formularon hipótesis en la búsqueda del uso de diferentes dispositivos de control y re-direccionamiento de la luz solar al interior de los espacios de oficina, que le permita a los usuarios de las oficinas controlar el deslumbramiento que es el principal problema presente en el clima tropical. Esta investigación concluyó que aunque se han realizado ya exploraciones sobre el tema, un trabajo teórico-experimental representaría una aportación más a la tarea cotidiana de la investigación de mejorar los conocimientos sobre el control de la iluminación natural en los países de clima tropical.

Introduction

Natural light was the main source of illumination until recent times, basically until the 19th century, when with the arrival of the Industrial Revolution, there was a change in all the schemes proposed up to now. With the 20th century comes Modernism, a time when architecture finds its maximum expression, where internal spaces are transformed into spaces with open shapes. The two great currents of this new movement arose, European rationalism and organic architecture, whose greatest exponents include the “masters of modern architecture” who “learned to understand natural light as something more than a source of illumination”, referring to the Le Corbusier, the Swiss-French architect and the American architect Frank Lloyd Wright.

Under these considerations, lighting has been a leading part in architecture, and today, thanks to advances in research and technological development, it concerns both sources of lighting, the visual well-being of man and the search for lighting conditions. Ideally, both visual and thermal, that guarantee optimal development in your daily tasks.

“In the 1910s and 1920s, the world of the office changed radically. The specialization and standardization of office work, the systematization of work processes and their optimization to increase their efficiency constitute the basis of the new business structures.” [9]

Despite the advances and continuous efforts to innovate in technology that refers to the control and redirection of natural lighting, there are still great gaps and paths to explore, since in many cases, these advances have guaranteed great savings in energy consumption but not in the well-being or satisfaction of its users.

“The trend of the 21st century office is to build interiors that guarantee the fluidity of communication between its workers, not to build monuments to prosperity.” [6]

For this reason, although explorations on the subject have already been carried out, a theoretical-experimental work would represent one more contribution to the daily task of research to improve knowledge about the control of natural lighting in countries with a tropical climate.

Justification

The research is within the topic Sustainable Architectural Design.

The issue of taking advantage of natural light in the internal space of buildings, is becoming increasingly important in the field of research and development of architectural projects worldwide, this boom is due to the energy crisis that forces to seek sources of alternative energy and make intelligent use of natural light that allow reducing the costs of maintenance and operation of office spaces, which in the specific case of Costa Rica, represent one of the largest sources of energy consumption in non-industrial sectors, residential.

Hypothesis

The hypothesis is based on the viability possible for the use of natural lighting in office spaces those located in San Jose, Costa Rica, and effectiveness employ scale models combined with measurements on site and programs for energy simulation for determine their use in the study area.

General Objective

“Proposal for a natural lighting system, which determines the viability of the use of natural light in office spaces, located in the tropics of Costa Rica.”

Specific Objectives

1. A study of the existing sky and daylight availability in the study area to determine their use in scale models, measurements on site and energy simulation programs.
2. Study of the climatic conditions of the tropics of Costa Rica, and their influence on the office space.
3. Analysis of existing offices in Costa Rica, to diagnose the main light and spatial conditions, within a real operating scheme.

4. Evaluation of solar control devices capable of capturing, conducting, reflecting, redirecting, and diffusing the incident sunlight in the façade openings of office buildings, to determine the viability of its use in San José, Costa Rica.

Methodology

Scientific support is based on general systems theory.

According to [2] an Israeli researcher, recommends that the design of buildings in a hot-humid climate should be oriented towards the search for:

1. Minimize heat gains through the enclosure.
2. Maximize the building's nightly cooling hours.
3. Promote effective natural ventilation, even in rainy seasons.
4. Prevent rain penetration, even during storms.
5. Prevent the entrance of insects while the windows are open for ventilation.
6. Provide transition spaces such as porches, between the exterior and the interior that are part of the building." [2]

To carry it out, in the first stage, an exploratory study was carried out to search for bibliographic references, which made it possible to determine the basic concepts, terminology and factors that intervene when measuring and controlling natural light in an internal office space. "Thus, shading devices and small openings are considered as the main features of building design to control excessive penetration of directional sunlight, in order to reduce heat gain and glare." [10] suggested that the principal objective of sub-tropical window design is thermal comfort in summer, generally requiring the exclusion of sunlight from interior spaces. Therefore, daylight entering the windows is severely reduced and internal daylight levels in shaded sub-tropical buildings are well below those achieved in buildings in more temperate climates". [2]

An experiment was carried out in 6 stages, the first two with scale models and the other four in real buildings, with the aim of measuring the outdoor lighting available in San José, Costa Rica, as well as its level of admissibility to the internal space of the buildings. Offices, physical variables and therefore quantifiable.

"These models, as an analysis tool, are absolutely reliable for taking data on light levels indoors, since electromagnetic waves in the visible spectrum have a size in the range that goes from 380 to 750 nanometers, for what they affect and are reflected in the scale model, in the same way that they would in the real place. The differences, if any, could not be perceived by the human visual system, nor the differences in amount of luminance, brightness and distribution between the two. In addition, this method allows evaluating the quality of the illuminated space by direct observation or by photographic record." [7]

Based on the knowledge obtained in the experimental stage, a proposal was made that is evaluated with the Ecotec energy simulation program, owned by the Autodesk company, where the efficiency in the use of a light tray and the variation in the geometry of the false ceiling, in the tropical context of the study area.

Experimentation in models and buildings

An experiment was carried out, based on the construction of a three-dimensional office space model, with the aim of quantifying the resulting natural illuminance levels in the internal space, as a result of the incidence of direct and diffuse radiation on its façade.

The data collection process for the experimentation stage was carried out in Costa Rica, twice a day, during the morning with time slots of 8:00 and 10:00 a.m. and at noon around 12:00 and 1:00 p.m., lasting four days at the end of August.

The following variables were analyzed:

1. Internal illuminance under different types of sky.
2. Influence of the reflectance of the internal surfaces.
3. Effect of the use of solar control devices inside the model.

Sky conditions: the mock-ups of models No. 1 and No. 2 were used to measure the distribution of internal illuminance within a unilateral and a bilateral lighting scheme, respectively, and the values obtained in terms of uniformity under different conditions (see figures 1 and 2).

a) b) c)

Figure 1. Models in scale: Unilateral Illumination. a) Exterior view, b) interior space, and c) model plan.

a) b) c)

Figure 2. Models in scale: Bilateral Illumination. a) Exterior view, b) interior space, and c) model plan.

Reflectance on the internal surfaces: the reflectance of the internal surfaces was varied in models No. 1 and No. 2, through the use of light yellow cardboard, placed on the walls adjacent to the façade with a window and a medium gray cardboard, for the floor area (see figure 3).

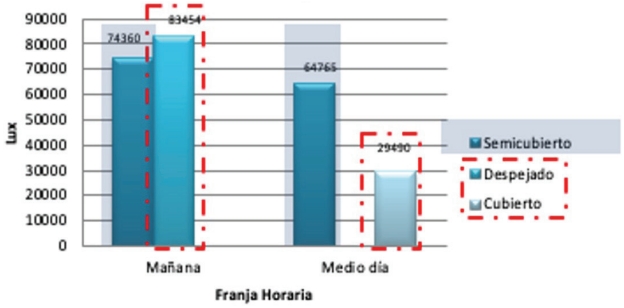

Figure 3. Global exterior lighting on the horizontal plane, analysed in two time bands.

Solar control devices: the solar path was studied for latitude 10° north, to carry out the dimensioning of the solar control devices. 2 shade devices were proposed, made up of 3 horizontal slats with the same characteristics: rectangular in shape with dimensions 40 cm wide x 132 cm, along the entire length of the window x 0.02 thick, the devices were painted in matt white, and they were located 10 cm inside the wall of the window wall, only varying the degree of inclination of the slats at 45° and 0° (see figure 4).

Figure 4. Experimentation in models.

Experimentation in real buildings

From the aforementioned stage of experimentation which allowed creating a first diagnosis of light behavior in the tropics of Costa Rica, the first conclusions and the drafting of some recommendations are raised with the aim of proposing the solutions that best suit this type of climate, and in turn, the need to carry out a second experimental analysis exercise was detected, but this time within an existing office space, which would allow evaluating it under much more objective conditions (see figure 5).

The evaluated variables were:

1. Type of exterior enclosure of the building at the façade level.
2. Characteristics of the internal space.
3. Arrangement of office furniture.
4. Office user.

Architectural shading solutions are typically part of the exterior facade. Light shelves, overhangs, fins, shade screens, venetian blinds, vertical blinds, miniature louvers, and roller shades are commonly used shading systems. One drawback of using shading devices is the risk of reduced daylight level, as all shading devices reduce the view of sky, which is a potential source of daylight. This can increase the use of artificial lighting for interior task.

Figure 5. Experimentation in real buildings.

"Therefore, a good vision of objects depends on the inert visual capacity of each person, the amount of light available to carry out the task and the appropriate distribution of light that allows a correct visual adaptation, taking into account that illuminance and brightness distribution are essential criteria for achieving good lighting" [5]

Results

The low level of natural lighting present at the points furthest from the front window opening.

The sensation of glare and visual dis-comfort caused to the office workers, as a result of the incidence of direct solar radiation to the internal space.

These problems fall on solutions that, as verified in the experiment, in stages N°3, N°4, N°5 and N°6 in real buildings, are solved in practice, with the activation of artificial light in a way constant throughout the day.

The study and investigation of the use of natural light in internal spaces has allowed the best use of this inexhaustible source of energy, through its control and redirection to the interior space.

Conclusions

The use of special glasses on the facades of the buildings or with the reduction around the window opening, represent not very efficient solutions from the point of view of taking advantage of natural light and are also quite expensive for most of the users of the study area.

Therefore, the use of a light tray, commonly used in other climatic contexts, was proposed, which will function as a protection device and redirect sunlight, and in this way achieve increase the low levels of natural lighting present in the points farthest from the façade, as well as the control of direct solar radiation incident on it.

It was found that the variation in the shape of the false ceiling in an office space represents a valid tool for homogeneously distributing incident natural lighting throughout the space.

Natural lighting plays a predominant role in the task of achieving the visual well-being of workers, in the ideal lighting conditions of the office space, and when it comes to guaranteeing optimal performance in their daily work.

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