Natural Light as an Interior Lighting System Through Fiber Optic Transmission in Paraguay

Oscar Díaz
Graduate Student
Universidad Nacional de Itapúa
Encarnación, Paraguay
mge.oscardiaz@fiuni.edu.py

Ramón Martínez
Graduate Student
Universidad Nacional de Itapúa
Encarnación, Paraguay
mge.ramonmartinez@fiuni.edu.py

Jorge Kurita
Professor and Research Director
Universidad Nacional de Asunción
Asunción, Paraguay
jkurita@fiuna.edu.py

Abstract

This research has carried out the analysis of the efficiency of natural light as an interior lighting system through fiber optic transmission in Paraguay as a pioneering alternative to energy demand.

For its analysis, the construction of a flat concentrator in the shape of a truncated pyramid was carried out, with a metal support equipped with rotational movements both in the x and y planes in such a way as to manually track the sun. At the light concentration point, a support was placed for the 6mm diameter and 10-meter-long optical fiber that transports the concentrated light from one end to the other. This light transmission was measured with a luxmeter to determine the amount of illumination from the concentration point to the end of the fiber.

It has been observed that, for an illuminance of 109,200 lux coming from the source (sun) with an orientation of 40º North and with an inclination of 27º with respect to the normal, the illuminance obtained at the end of the fiber located in a totally isolated room of the source was 21,600 lux at the surface of the optical fiber. In addition, the light beam projected by the optical fiber has an opening angle of 60º.

Given that the room to be illuminated with the natural light source has artificial light that projects an illuminance of 80,800 lux on the surface of the lamp, it is estimated that 8 (eight) points of natural light will be necessary for said room for adequate lighting.

Keywords

Fiber, Optic, Natural Light, Efficiency.

1. Introduction

The objective of this article is to analyze natural light as an interior lighting system through fiber optic transmission in Paraguay.

The activities carried out within our country are day and night tasks that necessarily entail the use of electrical energy for their development. Lighting is something inherent to these activities, since without it, they could not be carried out. The artificial lighting system is the most widely used lighting source for interior tasks in our country, leaving natural lighting alone for exterior tasks. Since the building structures themselves are not designed to take advantage of light as a lighting system, but only as a means of indirect lighting through their windows.

For this reason, an attempt is made to answer the questions that could provide a solution to the problem posed: How to concentrate natural light for its subsequent transmission into the home? How much light would be concentrated? Will there be losses in the hub and fiber optic system? By what percentage would sunlight replace artificial light?

The management of natural resources is everyone's commitment, so the search for a reduction in electricity consumption is a clearly viable means of achieving this goal. By reducing consumption, a series of events will be derived, such as the reduction of the power necessary for activities, therefore, a less saturated electrical system.

Also, through the use of natural lighting in the various properties, it is intended to reduce the column of fixed expenses of the owners observed in their electricity bill at the end of the month.

Through this research, it is desired to achieve not only the reduction of pollution or the reduction of economic expenses due to electricity consumption, but also the use of sunlight, which is a little exploited resource in our country.

1.1 Objectives

The objective of this article is to analyze natural light as an interior lighting system through fiber optic transmission in Paraguay.

2. Methods

The design of this research was of the experimental quantitative type since "one or more independent variables (supposed antecedent causes) are intentionally manipulated, to analyze the consequences that the manipulation has on one or more dependent variables (supposed consequent effects), within a control situation for the researcher" (Fleiss, 2013; O'Brien, 2009 and Green, 2003).

The measurement of natural lighting was carried out inside a room isolated from the light source (sun) so that it does not influence the results obtained. It has an area of 12 square meters, dark green walls and a brown roof.

Outside, the day was clear in such a way as to obtain measurements with high parameters in relation to the illumination coming from the source (sun). In the place, it was decided to locate the solar concentrator of the flat truncated pyramid type with a support equipped with movements both in relation to the x axis and also in relation to the y axis. This in such a way to perform solar tracking manually.

Measurements were taken using a MINIPA digital lux meter with a measurement range of 2,000/20,000/100,000 lux.

As for the optical fiber, a PMMA plastic type of 6mm diameter and 10 meters in length was used. Which has been supported by means of a solid support at the end of the concentrator and laid linearly (from the concentrator to the room) in such a way as to avoid curvatures that can cause reflection losses.

The data was taken using the observation method and varying the position of the concentrator manually. In addition, the measurement of the existing artificial light in the room (investigation medium) consisting of LED lamps of 12 watts of power was carried out.

The analysis of both systems was carried out by comparing the readings taken from natural light and artificial light in the same room.

3. Data Collection

The data was tested using a digital lux meter that has ± 4% accuracy up to 10,000lux and above this value ± 5%. Its repeatability is ± 2% and it is calibrated with a 2856ºk incandescent lamp standard. It also has a silicon photodiode photosensor and its value correction is carried out by the cosine rule.

This instrument has been chosen since what we want to know is the illumination of both systems in addition to the same source (sun).

To carry out the measurement, the illumination of the source (sun) was first measured, this measured directly on a clear day with an orientation of 40º North and with an inclination of 27º with respect to normal. The illumination reading was also taken at the point of concentration of sunlight at the outlet of the flat concentrator.

Subsequently, we proceeded to take a reading of the lighting inside the room isolated from the source (sun) of both systems at different distances from their focus. As for natural light, its opening angle was also measured.

4. Results and Discussion

4.1 Numerical Results

It has been observed that, for an illuminance of 109,200 luxes coming from the source (sun) with an orientation of 40º North and with an inclination of 27º with respect to normal during a clear day, the illuminance obtained at the end of the optical fiber in a point located in a room totally isolated from the source was 21,600 luxes at the surface of the optical fiber. In addition, a reading of the illuminance was taken at the outlet of the flat concentrator, observing a magnitude of 67,332 luxes.

It has been observed that, for an illuminance of 109,200 lux coming from the source (sun) with an orientation of 40º North and with an inclination of 27º with respect to the normal, the illuminance obtained at the end of the fiber located in a totally isolated room of the source was 21,600 lux at the surface of the optical fiber. In addition, the light beam projected by the optical fiber has an opening angle of 60º.

Given that the room to be illuminated with the natural light source has artificial light that projects an illuminance of 80,800 lux on the surface of the lamp, it is estimated that 8 (eight) points of natural light will be necessary for said room for adequate lighting. (Figures 1, 2, 3 & 4)

4.2 Graphical Results

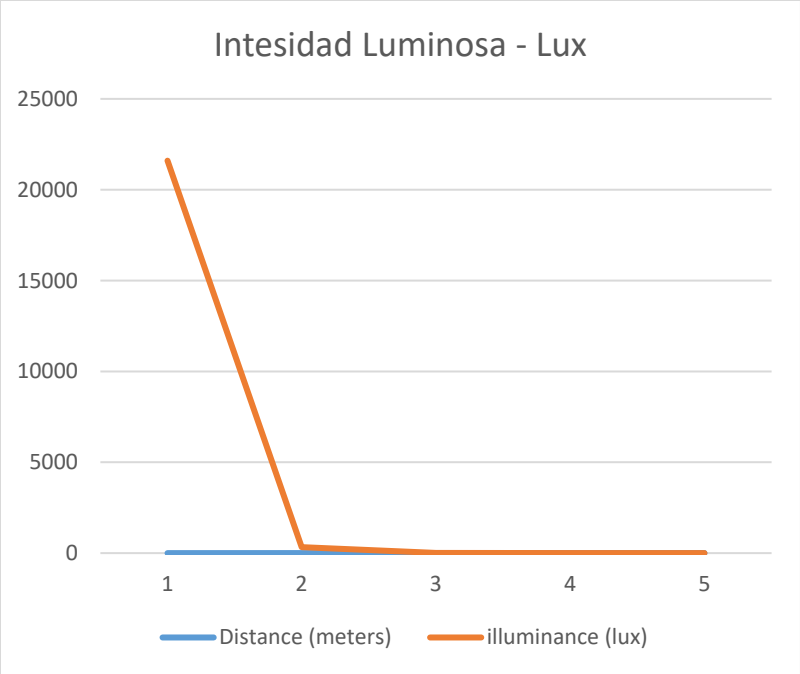

Figure 1. Illuminance values of natural light

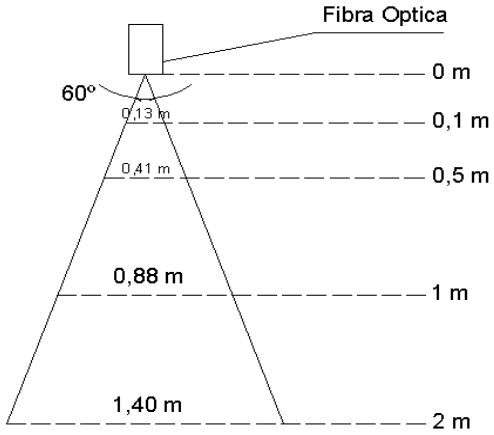

Figure 2. Natural light beam opening cone

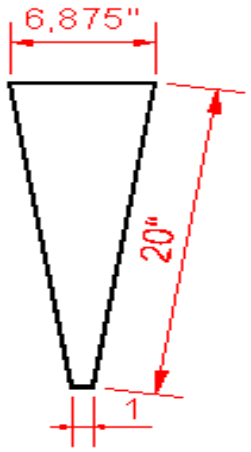

Figure 3. Dimensions of the solar concentrator

Figure 4. Beams of lights at the outlet of the concentrator

4.3 Proposed Improvements

It would be good to increase the amount of light that can be captured with a magnifying glass-type concentrator system, where the intensity of light captured would be improved.

5. Conclusion

Solar light could be concentrated by means of a flat mirror concentrator in the shape of a truncated pyramid, although it was observed that greater concentration can be achieved with covalent mirrors.

- With this concentrator, only 62% of the sunlight from the source (sun) is concentrated, 38% are beams of light that are reflected back to the medium.

- The existing loss in the hub-fiber system is 68% and only 32% is used as a lighting source.

- 8 (eight) points of natural light would be needed to be able to replace the artificial light source, but a mixed system would be needed to be able to provide the system with reliability.

References

Burkhard, D.G., Strobel, G.L. and Burkhard, D.R., Flat-sided rectilinear trough as a solar concentrator: an analytical study, Applied *Optics*, vol. 17, no. 12, pp.1870-1881, 1978.

Burkhard, D.G., Strobel, G.L. and Shealy, D.L., Solar concentrating properties of truncated hexagonal, pyramidal circular cones, *Applied Optics*, vol. 17, no.15, pp. 2431-2440, 1978.

Fang, Y., Feuermann, D. and Gordon, J.M., Maximum-performance fiber-optic irradiation with nonimaging designs, *Applied Optics*, vol. 36, no. 28, pp.7107-7115, 1997.

Fleiss, J., Bruce, L. and Myunghee Cho, P., Statistical methods for rates and proportions, *John wiley & sons*, 2013.

Grisé, W. and Patrick, Ch., Passive Solar Lighting Using Fiber Optics, *Journal of Industrial Technology*, vol. 19, no.1, November 2002 to January 2003, pp. xx-xx

Kribus, A., Zik, O. and Karni, J., Optical fibers and solar power generation, *Solar Energy*, vol. 68, no. 5, pp.405-412, 2000.

Leutz, R., Suzuki, A., Akisawa, A. and Kashiwagi, T., Shaped nonimaging Fresnel lenses, *Journal of Optics A: Pure and Applied Optics*, vol. 2, pp.112-117, 2000.

Malacara, D., Optic basic, *Editions Scientific University*, no. 3, pp. 81-98, 2015

Feuermann, D. and Gordon, J.M., Solar fiber-optic mini-dishes: A new approach to the efficient collection of sunlight, *Solar Energy*, vol. 65, no. 3, pp. 159-170, 1999.

Maliek, H. A. and Taban Al-Mosawi, T. Z., Optical Design Optimization for Indoor Solar Illumination Using Truncated Tetrahedral Pyramid Concentrator, *Eng. &Tech.Journal*, vol. 32, part (B), no.3, 2014, pp. xx-xx

O'brien, J., Akira, F. and Jelena, V., Photonic quantum technologies, *Nature Photonics 3*, no. 12, pp. 687-695, 2009.

Green, M., Crystalline and thin-film silicon solar cells: state of the art and future potential, *Solar energy 74*, no. 3, pp. 181-192, 2003.

Biography

Oscar Díaz. Born in the city of Encarnacion 12/15/1982. Of Paraguayan nationality. I grew up in Ciudad Capitan Miranda where I did elementary school. I did high school and college in Encarnacion, graduated as an Electromechanical Engineer at the National University of Itapua. I exercise the profession in the area of construction and education. I have a specialization in university teaching at the Catholic University.

I developed in the work area in electromechanical installations in low voltage and medium voltage. Enter the postgraduate master's degree in Energy Management and currently in the thesis stage.

Ramón Martínez. Born in the city of Santa María Misiones of Paraguayan nationality on February 13, 1988. Graduated from the National University of Itapúa in the Electromechanical Engineering career in 2013 He completed a Specialization in University Teaching at the Postgraduate School of the National University of Itapúa in 2017.

Currently in the thesis stage in the postgraduate study in Master of Energy Management with an emphasis on Technology since 2019 I have been working since 2013 as an electromechanical engineer at the Inter Electric company, performing tasks in the building installations sector, both in low voltage and medium voltage.