APPLICATION OF AN ANIDOLIC SYSTEM TO IMPROVE DAYLIGHTING IN EDUCATIONAL BUILDINGS

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ABSTRACT

The suitable interaction of daylight is an essential issue to reduce the energy consumption in buildings and to improve luminous comfort conditions of occupants. The aim of this work focused on investigating the potential of anidolic systems to enhance the daylighting conditions in an educational building whilst providing comfort for the students. Previous research has demonstrated the effectiveness of these systems [1, 2, 3, 4, and 5]. The case study building is a computer classroom of an elementary school located in the Mexico City Metropolitan Area (MCMA). During the first stage of this work, evaluation of the lighting conditions of the investigated space was carried out. Results indicated that natural light in the space was low and inadequate in most working stations. The physical and optical properties of the envelope components of the space were replicated in a 1:15 scaled physical model. The calibration process of the lighting conditions in the model showed similar conditions as in the actual building and then validated the procedure. Five different anidolic alternatives were implemented, investigated and evaluated in a scale physical model, located on the north facade of the case study space. These alternatives, assessed experimentally, showed a significant improvement of working plane illuminances and daylight factors, monitored under clear and overcast sky conditions relative to the reference model with a conventional facade. As a result, a significant improvement of the daylight autonomy can be expected and was confirmed with the implementation of computer simulation models. The most promising results were shown by an innovative system consisted of an anidolic arrangement integrated with a refractive panel system, that increased the lighting conditions in the space whilst improving visual comfort and overall performance. It is expected that the results of this work can be applied in other similar buildings aimed at providing suitable lighting conditions whilst reducing the energy consumption and the emission of greenhouse gases to the atmosphere, and to eventually promote sustainability in buildings.

Keywords: Anidolic system, innovative daylighting system, educational buildings, sustainability

INTRODUCTION

Natural light has played an important role in architecture since the first constructions of the human habitat. Nowadays, it is uncontroversial that light is a fundamental premise in architecture and that it must be considered to accomplish luminous and visual comfort for the building´s occupants as well as energy savings.In most buildings, with its climatic variations, natural light can be the ideal, clean, free and efficient solution for energy savings and for the provision of luminous comfort conditions for the buildings occupants. The use of daylighting can also improve the health conditions of occupants in their work environments, particularly through physiological responses such as the regulation of the circadian rhythm and synthesis of vitamin D, and limit some detrimental effects of artificial light. Besides, the use of natural light in buildings implies the use a renewable energy source, which is a sustainable approach that reduces the emission of the greenhouse gases to the atmosphere.Therefore, natural light is an essential issue to be considered in any building from the conceptual design to the final documentation and construction stages. This research deals with the utilization of natural light by means of the implementation of anidolic systems applied in an educational building.

These systems incorporate the non-imaging optical principles used in a parabolic geometry to capture sunlight or daylight from the sun and the sky, concentrate the light into a focal point, and then redirect it into the building interior, and unlike the typical sidelighting systems that can perform fine under clear sky and sunny conditions, the anidolic systems perform well under overcast skies. This is due to its high concentration factor of its parabolic geometry that can use even the diffuse component of solar radiation and under direct solar radiation, without the use of any sun tracking mechanism [6]. Furthermore, anidolic systems, as static devices, minimize light losses and can accommodate a large spectrum of solar angles, which makes them suitable for most locations, during daily and seasonal changes and for a wide variety of building openings orientations. These type of systems were investigated and evaluated in this work.

RESEARCH OBJECTIVES

The objective of this work focused on investigating the potential of anidolic systems to improve the daylighting conditions in an educational building whilst providing visual comfort for the students. The case study building is a computer classroom of an elementary school located in the Mexico City Metropolitan Area (MCMA) (Figures 1 and 2).

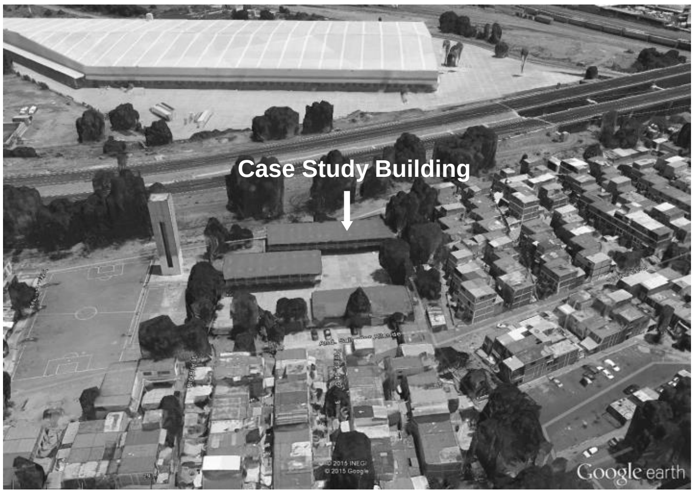

Figure 1: Aerial View of Case Study Building

During the preliminary evaluation of the lighting conditions, it was found that these were inadequate and did not comply with the recommended illuminance levels of the buildings standards [7]. The most critical space was found to be the computer room (Figure 3). The daylighting strategies proposed and investigated in this research were implemented in this space. The orientation of its main façade windows is south-southwest direction.

Figure 2: Main Façade of Case Study Building

Figure 3: Internal View of the Computer Room

METHODOLOGY

During the first stage of this work, the illuminance levels and daylight factors of the computer room were measured, and results indicated that the values were below the recommended building standards and to fulfil them, electric lighting has to be on throughout the school day [7]. The use of three dimensional physical scale models was selected for the evaluation of the daylighting strategies proposed. The model used in this research is at 1:15 scale.

Scale models are useful tools for daylighting analysis since light, travelling at its particular speed, does not require any scaling corrections, as the wavelengths of visible light are too short (from 380 to 780 nanometres), relative to the size of physical models, thus light behaviour is the same in a scale model as in the full size building.

Figure 4: Internal View of the Model with an Anidolic SystemImplemented During Exterior Analysis in Real Sky Conditions

The photometric and geometry properties: Optical reflectance and transmittance values of the internal envelope components of the real building, such as walls, ceiling, furniture and floor, and glazing, respectively were considered in the experimental procedure (Figure 4). The illuminance measurements were taken according to the local regulation methodology for this procedure (NOM-025-STPS-2008) in 25 points at desk level (0.75 mt).

Calibration of the model was conducted, measuring its illuminance levels and compare them with those of the computer room to guarantee that its optical properties were identical as those of the real building. Illuminance levels and Daylight Factors were measured in the 25 points of the space for assessing its quantitative performance, and photographs, from viewports, were recorded for qualitative analysis. The experimental evaluation was conducted under clear skies with real sky conditions, as the best possible scenario, and under an artificial sky using the CIE Standard Overcast Sky approach, as the worst possible daylight scenario (Figure 5).

Figure 5: Internal View of the Scale Physical Model with an Anidolic System in the artificial sky

The basic geometry of the anidolic systems evaluated is shown in Figure 6.

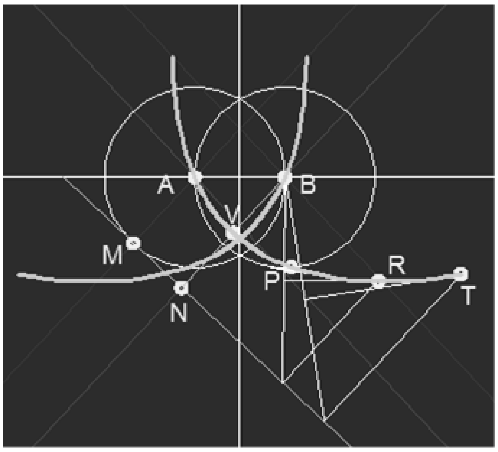

Figure 6: Basic Geometry of the Anidolic Systems Investigated

The anidolic systems have the distinctive capability to gather and redirect daylight from the exterior of a building into its interior with minimal light losses and significantly increase the levels of natural light in a room, reaching deeper than other systems. The five anidolic systems selected for investigation were located on the north facade.

RESULTS

The experimental results were compared and complemented with the use of two computer simulation programs: Radiance, useful for daylighting and electric lighting analysis which is a physically accurate and comprehensive lighting and visualization analysis tool that calculates daylight factors, illuminances, luminances and daylight autonomy (Figure 7); and Daysim, which is a validated Radiance-based daylighting analysis software that models the annual amount of daylight in and around buildings and allows users to model a wide variety of dynamic and non-conventional façade systems such as light shelves, switchable glazing, including also complex electric lighting systems and controls (occupancy sensors, photocell controlled dimming, manual switches, etc.)

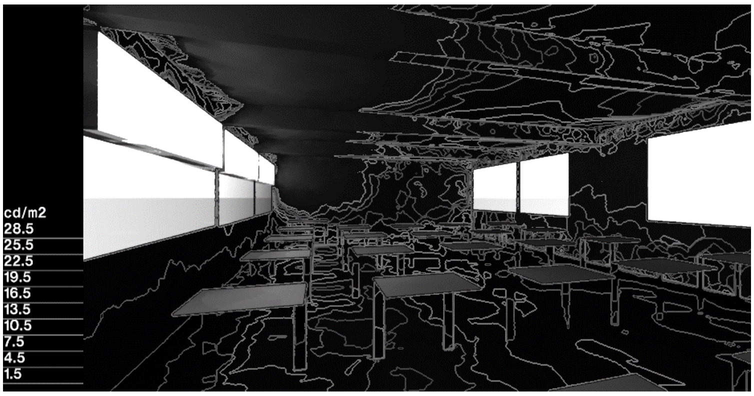

Figure 7: Luminance Values from Radiance. Summer Solstice at 12 hr

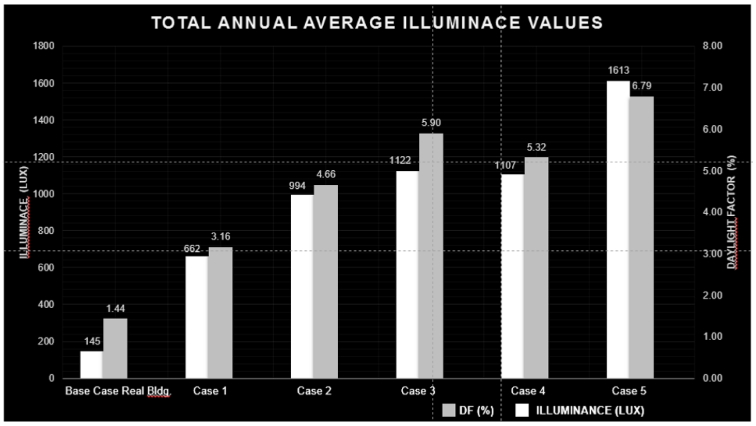

Figure 8: Annual Average Illuminance Values of all Anidolic Systems Investigated

ANALYSIS AND INTERPRETATION OF THE RESULTS

As shown in Figure 8, the anidolic prototype case 5 was the most promising alternative as provided an annual average of 1613 lux and 6.79 Daylight Factor (DF), relative to the base case without any system that registered 145 lux and 1.44 DF, respectively. The lowest values were obtained by Case 1. Cases 2, 3, and 4 were relatively similar, showing 994 lux, 4.66 DF; 1122 lux, 5.9 DF; and 1107 lux, 5.32 DF, respectively. Results indicated also that the use of a highly reflected film used in cases 2 to 5, provided better illuminance levels and DF´s. It was also observed that the use of a refractive layer implemented in cases 3, 4 and 5, increased the values recorded and reduced significantly the light losses, and that of case 5 was the most promising and exceeded the recommended values of the local building standards.

CONCLUSIONS

The results of this work clearly indicate that the use of natural light can have great benefits both in new and existing buildings, which can also have a positive economic and environmental impact; furthermore, the occupants can have direct benefits in their health conditions and productivity. The implementation of anidolic systems in particular has a great potential to improve natural light into the spaces both in quantitative and qualitative terms for the overall performance and visual comfort of the occupants so that their daily activities can be carried out properly and thus they should be considered as a suitable alternative. To sum up, it was demonstrated the potential of anidolic systems provided they are carefully designed and, that variables such as the latitude of the location and the geometrical characteristics of the building, among others, are taken into account. It is expected that the systems examined in this work can be applied in similar buildings aimed at providing economic and global environmental benefits, which in turn can improve the productivity, efficiency and health of the occupants, and eventually, develop a more appropriate quality of living for the present and future generations, promoting at the same time a sustainable living approach.

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