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# Optimization of an external perforated screen for improved daylighting and thermal performance of an office space

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**Abstract**

Glazed towers are predominant among commercial buildings built in recent decades. They advance the use of natural light, increase the visual contact with the outside and have a contemporary look. However, issues related to excessive daylight illuminances, glare and direct solar gains affect the visual and thermal comfort, and potentially increase the building energy demand. Passive design of protections is a key element to tackle these problems. A shading device consisting of a perforated screen is presented in this research with the aim of improving the Useful Daylight Illuminance (UDI), and reducing energy consumption and Daylight Glare Probability (DGP). The screen has been supposed to be used in an office space in Australia with windows on its north and west façades. Integrated daylight and thermal simulations have been carried out with the use of Rhinoceros/Grasshopper integrated specialist software. The geometry of the shading device has been optimized using Grasshopper integrated evolutionary optimization tool based on Genetic Algorithms. Size and distribution of the perforations in the solar screens have been chosen as optimization variables. Results, then, have been compared to a base case with no shadings and show significant improvements in UDI values, together with substantial reductions of energy consumptions and glare probability.


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*Keywords:* Shading device; perforated screen (PS); optimization; genetic algorithms (GA); useful daylight illuminance (UDI); energy consumption; daylight glare probability (DGP)

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## 1. Introduction

Glazed towers are predominant among commercial buildings built in recent decades, having been constructed all over the world in different types of climates and latitudes. They have a contemporary look and can increase the amount of natural light in the interior [1], which stimulates the visual and circadian systems [2]. Furthermore, they increase the visual contact between the inside and the outside of the building and the large glazed areas have a positive psychological effect because of the sense of openness of the space [3]. Evidence shows that users prefer to work in offices with daylight and visual contact to the outside, and that environments with no glare and comfortable in terms of temperature have positive effects on satisfaction and performance [4]. However, glazed façades in buildings may also cause some issues. For instance, direct sunlight in indoor spaces can produce excessive daylight illuminances, leading to visual or thermal discomfort of the occupants [4]. High levels of daylight in an office space are sometimes the opposite to optimum levels of visual conditions, being glare one of the major issues [5]. Excessive glare produce discomfort, reduction in the performance of users, and lighting changes that may increase the energy consumption [6]. In addition to daylight problems, there are also effects on the thermal performance of buildings. Daylight is just the visual component of the radiant energy that comes from the sun and, after it enters through the glass, a large percentage is transformed into thermal energy once it is reflected in the interior surfaces of buildings [7]. In Australia, office buildings are responsible for about the 25% of the total energy consumption by building type, and HVAC (43%) and lighting (26%) consume the 69% of the electricity in them [8]. Therefore, solar radiation should be controlled before it gets to the inside of buildings. This can be achieved by the use of shading devices and several examples are found in the existing literature.

A study of a Solar Screen in a desert climate was carried out in order to improve daylight, reduce glare and increase thermal comfort by analyzing its perforations [9]. Positive results were achieved and it was recommended to treat the screen of the south façade (northern hemisphere) differently in order to get better results. Another research of screens in desert climate reports that savings in energy consumption can reach values of up to 30% for west and south orientations in the northern hemisphere [10]. A research by Omidfar [11] assessed a solar screen with complex geometry in order to optimize the performance of indoor environments in terms of daylighting and energy. Results showed a reduction of annual energy use of respectively 35% and 42% in relation to the two baseline cases.

In terms of external horizontal elements, a research by Datta reported that louvres on south windows (northern hemisphere) can decrease the cooling loads for buildings in summer, while reducing the overall annual primary energy use [12]. In another research, an innovative shading device composed of tilted louvres, arranged to optimize the visual contact with the outside was studied and compared with three typical shading options (overhang, blind, and light-shelf). The new system produced better results than traditional systems, minimizing heating and cooling demand of internal spaces, and also providing maximized views of the outside [13]. External shading devices were tested in a research by Palmero-Marrero and Oliveira [14] for 5 different climates, concentrating on a typical single-zone office building with windows exposed to south, east and west. The system employed on the south façade was optimized to provide shading in summer and allow solar heat gains in winter. For east and west windows, a vertical layout of horizontal louvres was found to be beneficial in controlling light and solar gains. The developed systems were successful in reducing the energy consumption in the majority of climatic zones.

Genetic Algorithms (GA) are a powerful method in the process of finding optimized solutions for a large number of problems and have been widely studied in the field of the built environment. They mimic the process of natural selection where most powerful individuals are expected to prevail in a highly competitive environment, and a fitness value is utilized in order to assess how good these individuals are [15]. GA were part of a research to find a thermal and daylight optimized solution for placement and size of windows in a building [16]. In addition to the positive results achieved, when several runs of the same problem were done, solutions with similar environmental performance had variations. This gives flexibility to designers in order to select the preferred solution between different possibilities with very similar performance. Another research investigated an optimized shading device for a north façade window (southern hemisphere). Utilizing GA, the solution improved the daylighting illuminance levels and stopped the direct solar radiation decreasing the energy consumption [17]. A study by Karamata et. al. [18] developed an external shading, based on the Mashrabiya design principles, with a variable geometry capable of adapting to arid climates. The final goal of the research was to develop a system able to maximize the diffuse natural