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AN AUTOMATED HELIODON FOR DAYLIGHTING BUILDING DESIGN

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ABSTRACT

Daylighting building design offers real opportunities to achieve a part of the electricity savings potential of Switzerland. Design tools, however, are necessary to reach this goal in the practice.

A sun simulator was built to allow the study of the direct sunlight contribution to the lighting of buildings. It is made principally of an automated heliodon and a calibrated light source, installed in a carefully designed black chamber. By this way, visualizations of daylighted architectural spaces, as well as monitoring of direct daylight factors can be achieved in optimal experimental conditions.

The recognition of this equipment by lighting designers, ergonomists and architects confirms the importance of the latter one. It is a very good complement of the new infographic lighting design programmes developed recently for the same purpose.

KEYWORDS

Daylighting, design tool, automated heliodon, artificial sun, direct sunlight, direct daylight factor.

INTRODUCTION

Artificial lighting of buildings is responsible for a significant part of the national electricity consumption in Switzerland. Daylighting building design, associated to efficient light sources and control, offers on the other hand, real opportunities to achieve significant electricity savings at the national level (Brunner and collaborators, 1986).

Daylighting design, however, has a strong influence on the architectural aspect of buildings, as well as on the users visual comfort (Lam, 1986; Moore, 1989). Architects and lighting designers are the first concerned by this problem. They feel the need for user-friendly design tools, which could contribute to spread this new building and lighting technology in the practice.

A set of experimental tools, principally made of an ***automated sun simulator*** (heliodon) and an ***artificial sky***, is currently under construction at EPFL. Both equipments are expected to complete computer infographic daylighting design programmes developed for the same purpose. This paper gives an overview of the automated sun simulator, which is the first part of this equipment and already in operation.

DESCRIPTION OF THE EQUIPMENT

The aim of the sun simulator is the study of the direct sunlight contribution to lighting of buildings. This part is usually far bigger than the diffuse sky vault contribution; it is, on the other hand, responsible for the most frequent discomfort situations.

The sun simulator is expected to allow the following operations :

- measurements of direct daylight factors within scaled models of buildings,
- evaluation of visual comfort indicators for particular sun positions and daylighting systems,
- visualization of the qualitative aspects of the interior of buildings illuminated by daylight.

Figure 1 gives an overview of the different components of the automated sun simulator. Each of them will be described briefly.

THE LIGHT SOURCE

The light source, as well as the optical system, were chosen in order to reproduce the main physical features of the sunlight (spectral distribution, homogeneous illuminance, parallel light beams).

A short arc discharge lamp (OSRAM 2.5 kW HMI), combining high luminous efficacy ($\varnothing$ = 240'000 Lm, η = 96 Lm/W), daylight close spectrum (Tc = 5600 K) and high color rendering index (Ra $\geq$ 90), was used for that purpose.

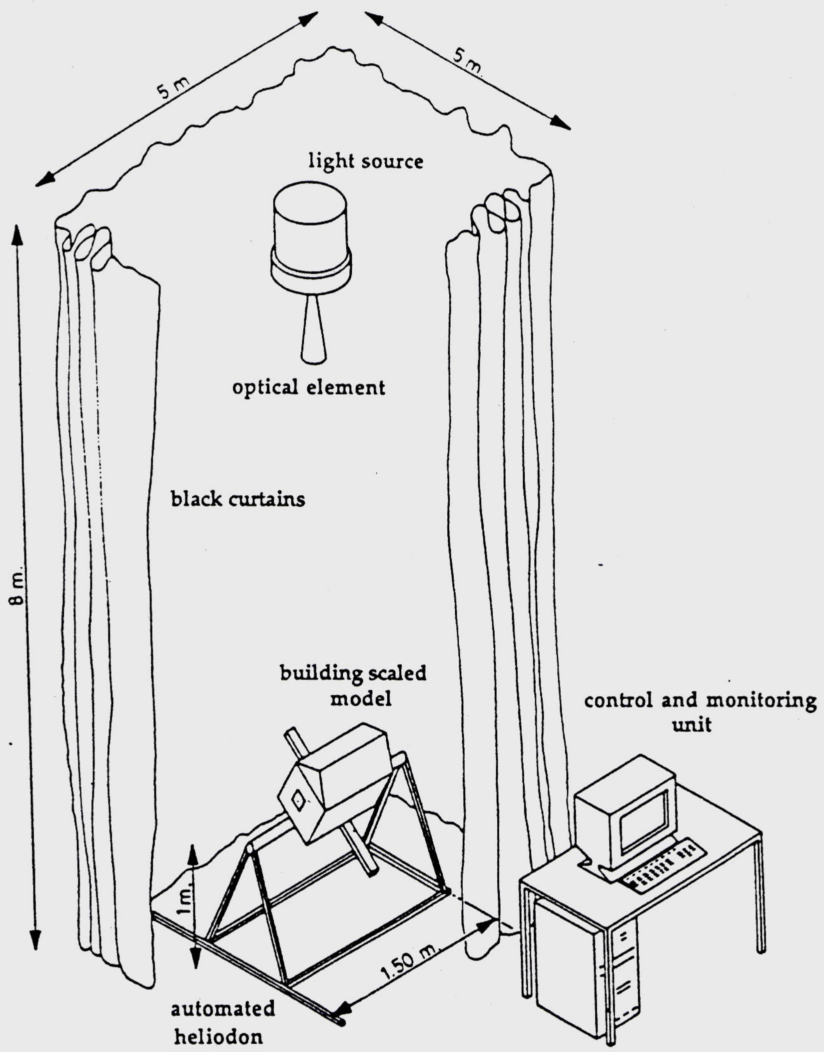

Fig. 1 Schematic view of the different components of the automated sun simulator (automated heliodon).

The original optical system is made of a movie floodlight projector (SIRIO Quartz Color Spotlight), characterised by an efficient hyperbolic reflector and a Fresnel front lens, as well as an adjustable beamwidth angle (8.3° - 74°). All this equipment was fixed at the ceiling of large room (8 meters above the floor), in order to get as close as possible to the source point configuration.

A supplementary optical element, designed to improve the uniformity of illuminance on the work plane (heliodon moving table) was added to the original optical system and placed underneath the spotlight. Two different basic shapes were considerated for this element (reflecting cone and disk). Fourty-eight different optical configurations, issued from the combination of up to four element geometrical characteristics (cone and disk size, cone length, distance from projector, spotlight beamwidth angle), were tested to get simultaneously the highest and the most uniform illuminance distribution on the work plane.

Figure 2 illustrates the measured optimal illuminance distribution. The average corresponding illuminance on the work surface is 2700 Lx (disk of 1.5 m of diameter on the floor); the uniformity on the same surface is 3.4% (the maximal illuminance obtained with the projector alone reaches up to 10'200 Lx with a uniformity of only 33%), showing a significative improvement compared to previous similar tentative of optimization of such an equipment (Fontoynont, 1987).

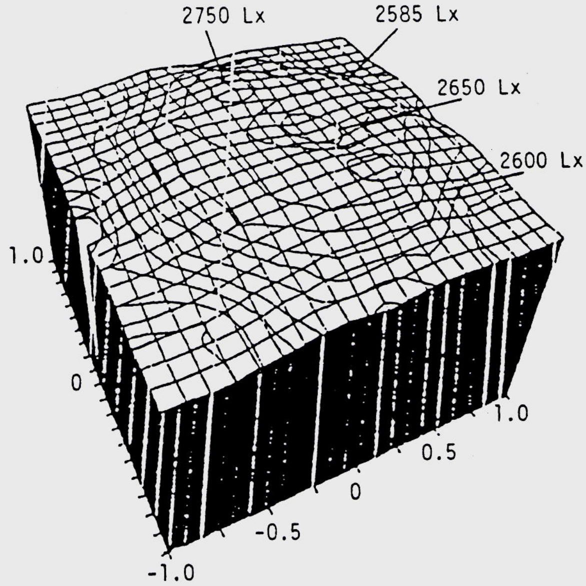

Fig. 2 Optimal illuminance distribution measured on the work surface of the equipment (disk of diameter 1.5 m).

THE AUTOMATED HELIODON

The heliodon is a mechanical device, which is able to reproduce the relative motion of the sun (simulated by the light source) for an observer placed on the moving work table (defined by a 1.3 m x 1.3 m black aluminium cross). Six different designs were considered before to start its construction. The final geometry, shown on figure 3, was chosen accounting for the following main criterion :

- absence of potential self-projecting shadows on the model,
- simplicity of the mechanical construction,
- movement continuity,
- minimal movements of the model center,
- maximal distance between the light source and the work plane,
- weight limitation.

The heliodon has two movable and motorized axis (DC powered motors). An adhoc gear technology (harmonic drive) was used to obtain a soft and gentle movement, as well as a maximal torque. It has the following main mechanical characteristics :

- accuracy of positioning : <1°
- movement speed range : 0 to 12 rpm
- maximal model size : 1.0 x 1.0 x 0.6 m
- maximal model weight : 25 kg.

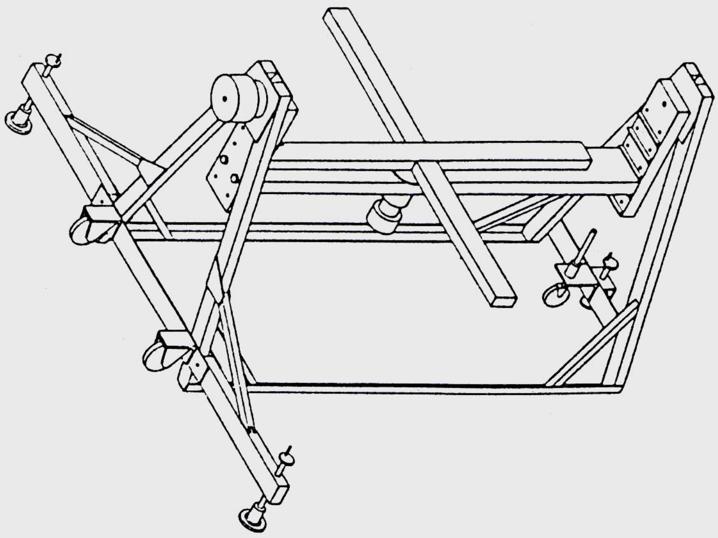

Fig. 3 Schematic view of the automated heliodon (the moving work table is made of a simple cross reducing the parasitic reflections).

THE CONTROL AND MONITORING UNIT

The two motorized axis of the heliodon are driven by a PC/AT 386 compatible. Different types of movement, accounting for the site latitude and longitude, the time of the year, the building orientation, are possible. These movements can be continuous, going from point to point, or reaching a defined position corresponding to selected sites, months, days and hours. The speed of the different movements can be chosen.

A serious effort has been dedicated to the way the users can interface with the machine. Accounting for the fact that architects, as well as lighting designers, are expected to be the principal ones, graphic inputs involving self explanatory symbols (icons), pop-up menus and mouse interactions have been employed at purpose.

To complete this equipment, different visualization and data acquisition facilities have been added to the control software. They include :

- an endoscope with corrected lens for architectural applications (real perspective),
- a high resolution video camera,
- a series of miniaturised photometers (sensor diameter of 4 mm).

The hardware is connected to the PC/AT 386 compatible allowing automatic data sampling of daylight factors, as well as output data plotting and treatment.

THE BLACK CHAMBER

All the experimental equipment, which has been described so far, was installed in a black chamber, built up for that purpose (see fig. 1). The black chamber was designed to offer the best experimental conditions during the operation of the sun simulator. It is made of black curtains, defining a space of 8 x 5 x 5 meters, which minimizes the incoming of parasitic external light (vertical illuminance smaller than 0.25 Lux even during a clear day). Internal reflections, due to the lighting of the curtains by the light source, were lowered by the choice of a black and matte tissue (reflection coefficient : 2.7%). The floor has been covered by a carpet of similar photometric features (reflection coefficient : 1.4%), reducing the risk of perturbating the measurements by unwanted light reflections on the floor. For the same reason, the heliodon has been painted with a dark black paint.

The careful design of the overall equipment has leaded to a very low expected experimental relative error (lower than 15%). The latter one involves all the different sources of error, which justifie all the procedures used to minimize their overall contributions.

CONCLUSION

A sun simulator, made of an automated heliodon and a calibrated light source, was built as an experimental daylighting design tool, principally aimed for architects. It is expected to allow an optimal use of direct sunlight within buildings in order to achieve lighting electricity savings and improve visual comfort.

The careful design of this equipment has allowed to minimize the different sources of experimental errors. This had an influence on the design of the automated heliodon itself, but also on the choice of the light source and its optical system, as well as on the construction of the black chamber hosting all the equipment.

The recognition of the usefulness of this tool by the architects, the lighting designers and the specialists of visual comfort, confirms the importance of the latter one in regards to daylighting design within buildings. It is expected in this way to be an optimal complement of the new infographic lighting design tools (Ward and collaborators, 1988) developed recently for the same purpose.

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