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Interactions between louvers and ceiling geometry for maximum daylighting performance

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ABSTRACT

The impact of ceiling geometries on the performance of louvers was investigated using physical model experiments and Radiance simulations. Two performance indicators, the illuminance level and its distribution uniformity, were used to assess daylighting performance in a room located in a subtropical climate region. It was found that the performance of the louvers can be improved by changing the ceiling geometry. The illuminance level increased in the rear of the room, and decreased in the front—near the window—compared to rooms having horizontal ceilings. Radiance results were found to be in good agreement with physical model data obtained under a clear sky and high solar radiation. Louvers' daylighting performance was reduced by tilting the louvers downward. The best ceiling shape was found to be one that is chamfered in the front and rear of the room.

1. Introduction

Using fossil fuel for lighting, cooling and heating buildings produces CO_2, which consequently causes environmental degradation. Buildings consume a large amount of energy for lighting and consequent space cooling [1,2]. Therefore, using daylighting in buildings will contribute significantly to the environment and economy. Moreover, daylighting has the potential to improve human health, mood, performance and productivity [3]. Consequently, economic potential of daylight is achieved not only by saving energy, but also by increasing workers' productivity in offices, factories, schools and retail premises [4–6].

Problems associated with using daylight in hot climate regions mean that daylighting is not the main concern in building design as the main concerns are to reduce heat gain, glare and direct light inside a building. Therefore, shading devices and small openings are considered to be the main features of buildings designed to control the excessive penetration of directional sunlight, in order to reduce heat gain and glare. The principal objective of subtropical window design is thermal comfort in summer, generally requiring the exclusion of sunlight from interior spaces [7]. Using shading devices reduces solar gains in buildings compared to non-shaded buildings. Therefore, internal daylight levels in shaded subtropical buildings are well below those achieved in buildings in more temperate climates [8]. Artificial lighting is the main light source, leading to greater use of air conditioning and ventilation systems in order to remove the associated heat. Energy used for lighting accounted for up to a third of electricity consumed in office buildings [1,2]. This is a contrasting situation because favourable natural lighting conditions are present during working hours and throughout the year [2]. Hence, the objective of an innovative daylighting system, in tropical and subtropical areas, is not only to provide the building with ambient daylight, but also to do that without these associated problems.

The purpose of this research was to maximize the daylighting performance of louvers, in regions with high luminous conditions, such as Jordan, by modifying ceiling geometries and louvers' parameters. The evaluation was based on two main indicators: the illuminance level and illuminance distribution uniformity. This study is limited to a south-facing aperture, where diffuse and direct sunlight were considered—in order to evaluate how the performance of louvers changes with modified ceiling geometries.

2. Louvers and blinds

Louvers are composed of multiple horizontal, vertical, or sloping slats of various shapes and different surface finishes. Louvers and blinds may be external or internal. They are used to partially or completely obstruct the sun's rays, and can be used in any direction and latitude.

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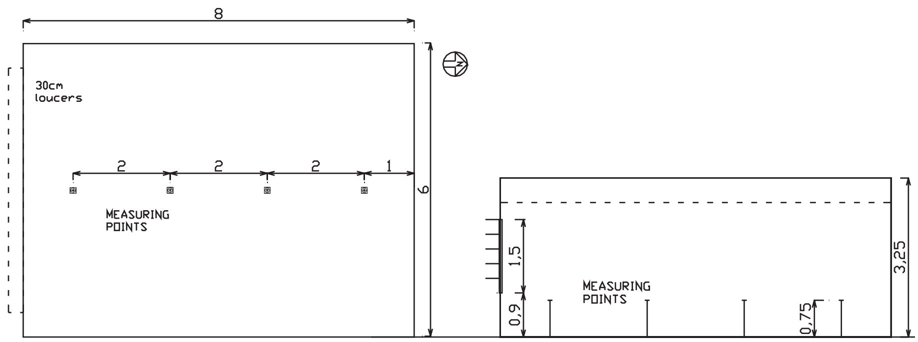

Fig. 1. The plan and a section through the testing room.

Horizontal louvers utilize both direct and diffuse sunlight, as well as ground reflections, and can be used in south and north directions. In sunny conditions, louvers and blinds can increase penetration of daylight derived from direct sunlight. In overcast conditions, they may also contribute to more uniform daylight distributions [9]. There are many types of louvers classified based on their materials and geometries, like translucent louvers, horizontal, curved, light-directed louvers and fish louvers.

Dubois [10] investigated the impact of seven shading devices on daylight quality in a standard individual office room. Forty-five degree Venetian blinds were found to be more suitable for VDT screen use, while horizontal louvers provided higher illuminance levels that suit traditional office work; both types provided an acceptable level of uniformity. The study showed that Venetian blinds were preferable as they performed many functions, i.e. controlling the high window luminance, providing acceptable illuminance and partially maintaining the outside view.

Littlefair [11] investigated the performance of many innovative systems. He concluded that the mirrored louver system:

1. Reduced the illuminance level, typically by 20–30%.
2. Improved illuminance uniformity in the room with better performance in summer compared to winter.
3. Tended to redirect some sunlight downwards in spring and autumn; this would cause glare to occupants.
4. Produced extremely bright points or lines under direct sunlight, which act as a glare source and could cause discomfort.

Mirrored louvers can only increase core illuminance under certain well-defined conditions—for sunny conditions in particular periods of the year. If they need to be used as shading devices, proper designs are required.

Chou [12] examined three types of shading device, horizontal, vertical and eggrate shapes. He tested variables like the depth of shading device, reflectance, opening ratio, and the fenestration design. Shading devices decreased the daylight factor in the range, 75–50%, and affected the daylight distribution, positively or negatively, depending on circumstances. Daylight decreased dramatically beyond the 3 m perimeter zone. Horizontal shading devices have the lowest influence on reducing daylighting compared to eggrates and vertical shading devices. Daylight factor decreased as the depth of shading devices increased.

Ng et al. [13] used louvers to improve the daylighting and lighting environment in an existing building used as a museum. Several variables were examined in Radiance to optimize daylight use in the building. Louver reflectance and slant angle were tested and their daylighting performance was compared to find the optimum setting. Parameters like uniformity, daylight distribution and daylight levels were used to evaluate the design options. Louvers improved the uniformity, but could significantly reduce the daylighting level if not properly designed. Ng et al.' study showed that louver angles have a greater effect on their daylighting performance than louver reflectance. Moreover, louvers are more effective as a control system, for shading and controlling sun rays, than low transmittance glass and curtains. However, there has been a lack of investigations into the effects of ceiling geometries on the daylight performance of louvers. The main purpose of this study was to provide information in this regard, and improve the daylight performance of louvers by modifying ceiling geometries and louver parameters. Physical models and Radiance simulation modelling

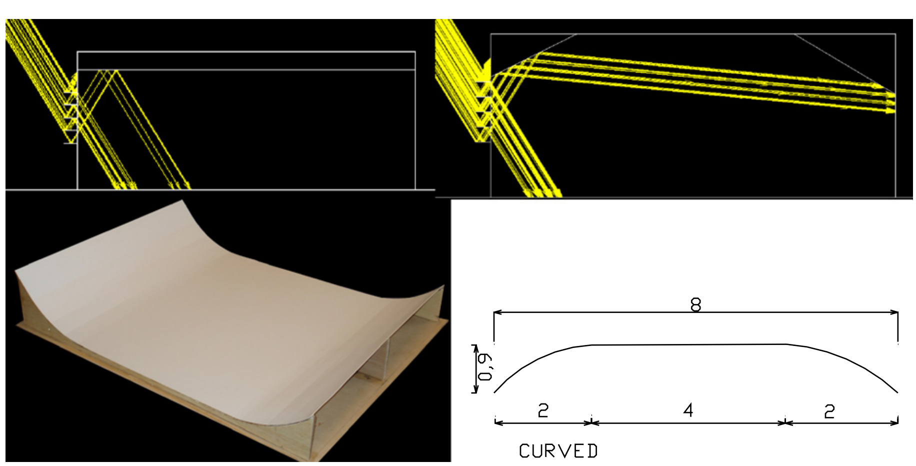

Fig. 2. Light behaviour in a room served by louvers and has a flat or curved ceiling (above) and a curved ceiling model with dimensions (below).