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# Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions

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**Abstract**

Large windows and highly glazed façades have been increasingly used in new buildings, allowing access to daylight, solar gain and external view. Sunrays passing through non-shaded windows and glazed facades significantly increases the air temperature in summer, especially in hot climates such as in Jordan. This negatively affects thermal comfort, increases the cooling load and becomes a source of glare, which harms the visual environment. The current research examined the effect of using shading devices on air temperature, visual environment and users' interaction in offices facing south-west façade at Jordan University of Science and Technology (JUST). Generally, shading devices are used to protect inner spaces from direct solar gain through openings, windows and large glazed surfaces. In such orientation, windows require special considerations to control solar gain, improve the visual environment and reduce glare. The research used real-time experiments and computer simulations to study how the shading devices will work in controlling air temperature and improving illuminance level. Three fixed shading devices (vertical fins, diagonal fins and egg crate) were installed in three identical offices in two stages: the first stage used temporary material while second one used improved design and permanent materials. Thereafter, the air temperature, illuminance level, thermal and visual environment were monitored and compared to non-shaded office. Computer simulations: IES/SunCast and Radiance were used to study solar and daylight distribution over the offices' surfaces around the year. The results showed that the temperature in offices with shading devices compared to the office without shading devices was reduced to acceptable level. Visual environment was improved by controlling the illuminance level, improving uniformity and eliminating glare. Offices with diagonal fins and egg crate shading devices performed better compared to the office with vertical fins and the base case.


*Keywords:* Shading devices; Thermal comfort; Illuminance level; Uniformity

## 1. Introduction

### 1.1. Shading devices

Buildings around the world require a large amount of energy for cooling, heating and lighting. Lighting in office buildings alone accounts for around 20–40% of total energy used in the buildings (Yang and Nam, 2010; Jenkins and Newborough, 2007; Li, 2010). Well-designed building require the integration of many factors, such as orientation, shading devices and building form, to reduce energy consumption throughout a building. In addition, windows, glazed façades and openings have an important role in building energy consumption whether for heating, cooling or lighting. Highly glazed façades and large windows have been increasingly used in new buildings, allowing access to daylight, solar gain and external view. Increasing the glazed area requires significant attention in building design in terms of its impact on cooling, heating and lighting demand. Proper shading design can contribute to indoor illumination from

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daylight, improve thermal comfort, control solar heat gains and reduce glare; however, this blocks the view out and generally affects the aesthetics of the building negatively.

Datta (2001) studied the effect of using shading devices on thermal performances of buildings in Italy. The study used TRNSYS computer simulation to study many variables related to horizontal shading devices in different cities in Italy. It found that shading devices could help to save energy and improve the thermal performance of buildings. Palmero-Marrero and Oliveira (2010) studied the effect of using shading devices on thermal performance in many cities in different latitude and climatic conditions using TRNSYS. The study showed that shading devices have a great impact on saving energy and improving thermal performance in offices in different climatic conditions. Bessoudo et al. (2010) and Tzempelikos et al. (2007, 2010) studied how shading devices effect thermal comfort in offices with glazed façades in a cold climate in Montreal-Canada. They studied interior glazing and shading temperature, operative temperature and radiant temperature under different variables such as Venetian blind, roller shade, and blind rotated angles. The study showed that shading devices could improve thermal condition in cold and sunny conditions. They also developed a transient building thermal model, which showed that increasing the size of windows does not produce a significant increase of useful daylight for a south-oriented office. Many researchers studied the effect of using of shading devices on thermal comfort, energy consumptions and daylight performance of buildings buildings (Freewan et al., 2009; Tzempelikos and Athienitis, 2007; Chou, 2004; Dubois, 2003; Lee et al., 1998; Wong and Agustinus Djoko, 2004; Sutter et al., 2006; Yoo and Lee, 2002). In hot climate regions, daylighting in building design is always sacrificed because of associated problems such as heat gain. Thus, shading devices and small openings are considered the main features of building design to control excessive penetration of direct sunlight so as to reduce heat gain and glare (Edmonds and Greenup, 2002). Edmonds and Greenup (2002) suggested that the principal objective of windows design in subtropical regions is thermal comfort in summer. Therefore, daylight entering windows is severely reduced and internal daylight levels in shaded sub-tropical buildings are well below those achieved in buildings in more temperate climates (Greenup and Edmonds, 2004). In hot climate regions with clear sky most of the year, this is a contrasting situation because the most favorable natural lighting conditions are present during working hours (Ochoa and Capeluto, 2006).

Freewan et al. (2009) studied the integration of louvers and ceiling geometry and their effects on daylight level in spaces in hot climate regions like Jordan, illustrating how shading design could be integrated with other building elements to improve daylighting environment. Dubois (2003) studied the impact of seven types of shading devices on daylight quality using Radiance to study the absolute and relative work plane illuminance and surface luminance. It was found that some shading devices could provide the offices with acceptable illuminance level suitable for traditional office work, while other devices could be used for computer-based work. Wong and Djoko (2004) investigated the daylight performance of shading devices using LIGHTSCAPE. They showed that shading devices can effectively reduce glare and allow for daylight to enter with illuminance level exceeding the recommended level. Gugliermetti and Bisegna (2006) developed simplified algorithms to assess the indoor natural illuminance with external fixed shading devices to simplify calculations shading devices performance.

Previous studies have shown that shading devices could significantly reduce energy used for cooling and lighting by reducing air temperature and controlling illuminance without glare. Previous studies focus on one or more variables of shading performance. Thus, literature has shown the need to show how the shading devices work under real conditions, the effect of shading devices on heat absorption by different surfaces, how shading devices affect the distribution of sunny and shaded areas and how to integrate the solar gain, glare elimination, daylight distribution, and spaces use in regions with a hot climate region like Jordan. Recently, with significant environmental awareness and energy saving, in addition to architectural developments, the daylighting benefits have been re-identified and should be part of shading and thermal gain study. Well designed and controlled daylight in buildings may well result in savings in energy consumption for lighting and improve the productivity of office workers; but this requires proving sufficient illuminance while avoiding the excessive daylight level, glare and solar gains resultant from large glazing areas.

### *1.2. Case study*

Jordan is classified as a subtropical area, which is characterized by hot and dry summers and cold winters. Clear sky conditions dominate throughout the year with medium to overcast sky and moderate rainfall in winter. The average direct sun component is generally about eight hours a day. The major characteristic of Jordan's climate is the contrast between a relatively rainy season from December to April and prolonged dry weather for the rest of the year. The country has a long summer with a peak in August while January is the coolest month (Table 1).

Jordan University of Science and Technology (JUST) is in Irbid (latitude 31.9° North, longitude 35.9° East), around 80 km north of Amman. The campus was designed by the Japanese architect Kenzo Tange. Buildings were constructed using prefab concrete panels and blocks. Offices are on second floors, while ground and first floors are used for lecture halls and labs respectively. The plan of the office levels, like wing A3 level 3, is double loaded corridor with offices at each side. The number of offices in south-west facade is 12 offices. The total area of an office space is 18.875 $m^2$, for which the width is 3.5 m, the depth