External Horizontal Fixed Shading Devices

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Solar protection is a passive strategy that directly influences thermal and visual comfort as well as heating, cooling, and lighting energy consumption of buildings. Using shading devices can produce some conflicts, such as the contradiction between winter requirements, summer comfort, and luminous comfort. This is why the shading device choice is a necessary issue for building design, especially in a hot and dry climate. Optimal solar protection must provide a maximum protection during the overheating period while permitting solar radiation penetration during the winter.

Keywords: solar shading devices ; daylighting ; energy saving ; thermal comfort ; numerical simulation ; parametric analysis ; hot and dry climate

1. Studies on Shading Devices

Many researchers have studied the effect of shading devices on thermal comfort, especially in a cold climate; Datta conducted a study for four different cities in Italy [1]and Tzempelikos et al. [2][3]performed an experimental study of the indoor thermal environment with different types of shading devices under Montreal climatic conditions in winter. Other studies were carried out in hot climate regions to evaluate fixed shading devices [4][5] and dynamic ones [6].

Certain studies focused on shading devices' effect on indoor factors; Dubois evaluated the daylight quality of shading devices [7]. Wong et al. studied the effect of external shading devices on daylighting penetration [8]. Freewan et al. [9] investigated the impact of ceiling geometries on the performance of louvers using two performance indicators: the illuminance level and its distribution uniformity. Datta[1] and Bessoudo et al. [3] evaluated the shading devices' effect on the thermal performance of building.

Several studies focused on energy consumption. Kim et al.[10] studied the external shading device effect in terms of energy savings for heating and cooling. Al Touma and Ouahrani [5] [11] conducted a study on shading and daylighting controls energy savings in offices with fully glazed façades in hot climates. Ossen et al. [12] studied the impact of solar shading geometry on building energy use in hot humid climates. Palmero-Marrero and Oliveira [13] studied the effect of louver shading devices on building energy requirements.

Cillari et al. [14] analyzed the effects of the integration of different passive systems' energy demand for cooling and heating and showed that fixed shadings led only to 1.28% energy saving in cooling and an increase in energy demand for heating by 0.46%. Hammad [10] demonstrated that the optimal static angle is -20° (i.e., 70° to the vertical) that resulted in a 31.36% reduction in energy consumption, which is about 34.02 for the dynamic facade.

Other studies explored both the luminous and thermal effect [15] [4][16][17]. Alzoubi et al.[18] assessed vertical and horizontal shading devices' performance in terms of daylighting and consumption; Vera et al. [19] focused on the optimization process of a shading device composed of curved and perforated fixed louvers, considering the visual comfort and energy consumption criteria. Kim [20] performed a series of simulations and measurements to evaluate the daylighting, energy and view performance of shading devices. Nielsen et al [21] studied the daylight and energy saving potential of automated dynamic solar shading in office buildings.

Settino et al. [22] performed a multi-objective analysis of fixed external solar shading systems with the aim of minimizing the energy consumption for heating, cooling and artificial lighting, while ensuring the visual comfort of the occupants, showing that the use of an optimal shading configuration allows a reduction in the annual energy consumption of up to 42%.

2. Design Parameters

2.1. The Ratio Between Slats Vertical Distance and Their Width s/l

Datta [1] studied three values of s/l (1, 2 and 0.92). Ouahrani and Al Touma [11] found that, for south orientation, a slat separation-to-width ratio of less than one (s/l< 1) saves between 27.6% and 35.0% of the space total energy demand,

eliminates glare visual discomfort, and
reduces CO_2 emissions.

2.2. The Spacing Between the Slats:

Oliveira [13] conducted a study of shading devices with a spacing of 0.23 m and 0.26 m depending on latitude. Hammad [6] from the United Arab Emirates set the spacing at 0.3 m and Alzoubi [18] from Jordan studied the case of spacing of 0.5 m; in both studies, the ratio s/l was equal to one, i.e., the vertical shading angle was 45. In the United Kingdom, Freewan [9] fixed the s/l ratio to the same value, and spacing between the slats was fixed at 0.05 m.

2.3. The Tilted Angle:

In a previous study [15], the effect of three tilted angles (60°, 90°, and 120°) on luminous and thermal conditions within spaces in hot climates was investigated. Hammad [6] and Alzoubi [18] both show that the total annual energy consumption and lighting level changes in correlation with the tilted angle of slats. Al Touma and Ouahrani [5] studied the impact of two tilted angles (45° and 90°) for north and south orientations. It was found that a tilted angle of 45° reduces energy demand by 7.7% and 18.6% for south and north-oriented offices, respectively; however, a tilted angle of 90 leads to 9.1% and 20.6% energy savings.

3. Conclusion

Shading devices could significantly reduce energy used for cooling and lighting by reducing air temperature and controlling illuminance without glare. However, they have a negative impact on heating loads because they reduce useful solar gains during the winter.

Most studies considered the Vertical Shading Angle (VSA) as a variable parameter, which changes according to the spacing between slats and their width, which means that shading either is not optimal during the overheating period or there is no sunshine in cold periods.

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