

# Planning for Daylight in Sunny Regions

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**Abstract**—Daylighting in buildings in sunny regions is not a simple task. This is due to the problems of heat gain, glare and fading and deterioration of materials associated with admitting natural light. Solving these problems requires careful consideration of climatic conditions and an understanding of the surrounding luminous environment. This study highlights the importance of using reflected global light as a main source of natural light inside buildings in sunny regions

**Index Terms**— Daylighting, sunny region, reflected sunlight.

## I. INTRODUCTION

Among the options for reducing energy consumption of artificial lighting is the effective utilization of daylight. In several studies concerning the use of daylight in office buildings, potential energy benefits have been demonstrated [1]–[5]. This indicates that daylight can be used as an important tool for passive energy conservation and therefore requires primary consideration in the initial schematic and preliminary design stages.

When designing for natural light under overcast sky conditions the designer can use simple, well established techniques, such as the daylight factor method and the average daylight factor method [6], [7], to calculate the internal illuminance. However, in the case of sunny skies the issue is different. Although, several tool for dealing with external and internal luminous environment have been proposed for different climatic conditions [8]–[14], daylighting in sunny regions need further investigations.

The design of buildings in hot sunny regions, in general, is influenced by several factors. Cultural, climatic, economical, social and technological factors are among the main ones. In such regions, due to the high intensity of solar radiation, the design of buildings will be very much influenced by solar gain. The utilization of natural light in such areas should be integrated with a range of thermal considerations that affect the geometry of a building. Problems associated with admitting natural light through windows in such regions are the effects of heat gain, glare and fading and deterioration of materials [15]. Solving these problems requires careful consideration of climatic conditions and an understanding of the surrounding luminous environment.

## II. PLANNING AND DESIGN IN IN SUNNY REGIONS

The subject of planning and design in hot regions has been

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addressed by several researchers and recommendations have been proposed [16]–[22]. These recommendations, mainly related to protection from the effects of solar radiation, have a major influence on designing for natural lighting. Proposed methods of protection from direct solar radiation may be classified into four categories:

### A. Protection at the urban level

Buildings in such regions tend to be closely grouped together in order to shade each other and to provide shade for the nearby spaces. The compact layout of buildings helps to minimize the exposed area of surfaces to direct sun radiation.



Fig. 1 A compact layout of buildings gives some protection from direct solar radiation [23].

### B. Reduction of Window Area

The size of the window is one of the key decisions in building design because of its effect on the interior visual, thermal and acoustic environment. Heat gain usually occurs more through glass than through a conventional wall of the same area. To minimize solar heat gain, windows in hot climates tend to be small in area.

### C. The use of shading devices

Shading devices can take several forms; horizontal, vertical and their combination. Another form of shading is the use of wooden screening devices that are popular in hot climates. Such screening is a protection against direct solar radiation and reduces the problem of glare.

### D. Choice of Orientation

In hot regions, orientation is a major issue from a thermal comfort stand-point. Movement of the sun across the sky will affect the quantity and angle of incidence of solar radiation on a vertical surface. Hence, different wall orientations will require different treatments of shading devices.

In general, the north and south facades receive less radiation gain if the appropriate shading device is used. Therefore, these are considered the best orientations from a thermal point of

view in hot arid regions. Openings on the west and east facades are not recommended due to the high heat gain and the difficulties in protection from direct solar radiation.

All the above forms of protection will affect the design and size of openings and the way of utilizing natural light in sunny regions. The use of shading devices, screens, small windows, and the compact form of layout of buildings will minimize the exposure of windows to sky and will not allow for direct sunlight inside the rooms. These factors, in addition to the low level of brightness of the clear blue sky in a hot climate [24], indicate that the optimum source of natural light is reflected sunlight. This is reflected from the ground, opposite facades, shading devices and from the screens in front of the windows. Because these tend to have high reflectance, often in order to minimise internal heat gain, the intensity of the reflected light is also often high.

### III. NATURAL LIGHT IN SUNNY REGIONS

Natural light reaching the interior of a room usually takes three forms: direct sunlight, direct skylight and reflected sunlight or skylight from nearby surfaces or from the ground. In order to utilize natural light, and in order to achieve the objective of good interior natural lighting, knowledge of the quantity and quality of the sources of natural light is necessary.

To highlight the importance of daylight as a quantity in sunny regions, Dammam city was chosen to highlight such issues. The Dammam city is located on the eastern coast of Saudi Arabia, north of the tropic of Cancer, at a latitude of 26° 30' North, and a longitude of 50° 09' East. The climate of the area is fairly complex. The eastern coast, as a whole, is classified as being in the Hot-Dry climate zone [17]. However, because the Dammam Area is located on the shoreline of the Gulf, the relative humidity is high, and the area may be classified as a Hot-Dry Maritime Desert [17].

The Area is characterized by two climatic periods, an extremely hot season, which lasts from May to October, and a relatively cool season, from November to April [25]. During the hot season, the temperature reaches a mean maximum of 46.7° C in July and August. In the cool season the mean minimum is around 6.3° C and 6.2° C in December and January (103). The mean maximum relative humidity exceeds 91% for the whole year. The mean minimum is around 20% for the whole year, except for the months of November (26.9%) and December (28.4%). . Annual rainfall is very low, around 71 mm annually [17].

In order to calculate the daylight illuminance from the available solar radiation data, the luminous efficacy will be used. The luminous efficacy of light is defined as the ratio of luminous flux (in lumens) to radiant flux (in watts) [24]. Therefore, any quantity of solar radiation measured at a given time can be converted into equivalent illuminance data, if the luminous efficacy of this radiation, at that time, is known. Several researchers have investigated the relation between solar radiation and daylight and numerous mathematical models were proposed. The most acknowledged sophisticated of these models is the one proposed by Perez and others [26]. This has been validated by data from different location with a very good performance [19,20]. According to this model, the

global ( $K_g$ ) and diffuse ( $K_d$ ) efficacies can be found by the following equation [26]:

$$K_g \text{ or } K_d = a_i I + b_i W + c_i \cos(z) + d_i \ln(D) \quad (1)$$

where:  $a_i$ ,  $b_i$ ,  $c_i$  and  $d_i$ =given coefficients (for diffuse or global efficacies) corresponding to the sky's clearness ( $e$ );  $W$  = the atmospheric perceptible water content; ( $D$ ) =the sky brightness. The sky clearness ( $e$ ) is given by:

$$e = [(I_d + I_n) / I_d + 1.041z^3] / [1 + 1.041z^3] \quad (2)$$

where:  $I_d$ =the diffuse irradiance,  $I_n$  is the normal incidence irradiance;  $z$ =the solar zenith angle in radians. The sky brightness ( $D$ ) is given by:

$$D = I_d m / I_E \quad (3)$$

where:  $m$  = the optical mass;  $I_E$  = the extraterrestrial irradiance. The atmospheric perceptible water content ( $cm$ ) is given by:

$$W = \exp(0.07T_d - 0.075) \quad (4)$$

where:  $T_d$  = the three-hourly surface dew-point temperature (°C).

Based on this Eq. (1), the horizontal diffuse illuminance ( $E_d$ ) and the horizontal global illuminance ( $E_g$ ) can be estimated by the following:

$$E_d = I_d K_d \quad (5)$$

$$E_g = I_g K_g \quad (6)$$

The solar radiation was obtained from the solar radiation measurements station (established by King Abdullah City for Atomic and Renewable Energy). Such station measure global, normal and diffuse radiation based on one-minute intervals (Fig. 2).



Fig. 2 Solar monitoring station at the roof of College of Architecture and Planning, University of Dammam, Saudi Arabia

Thus, based on the Equations. (1) to (6), the horizontal diffuse and global illuminance was estimated for Damam city from the available irradiance. The results are illustrated in Fig. 3 and 4.

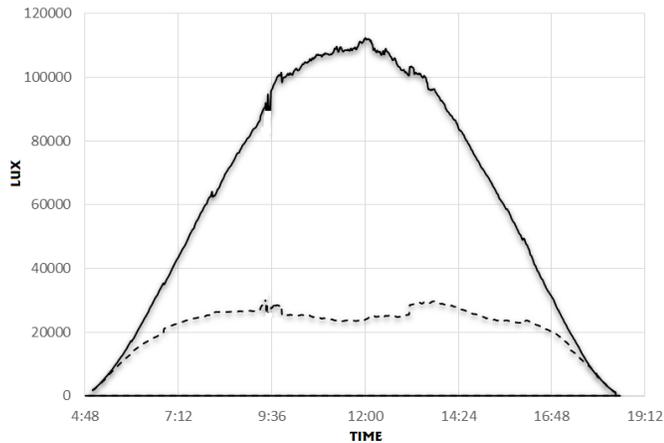


Fig. 3 Global and diffuse horizontal illuminance (21 June).

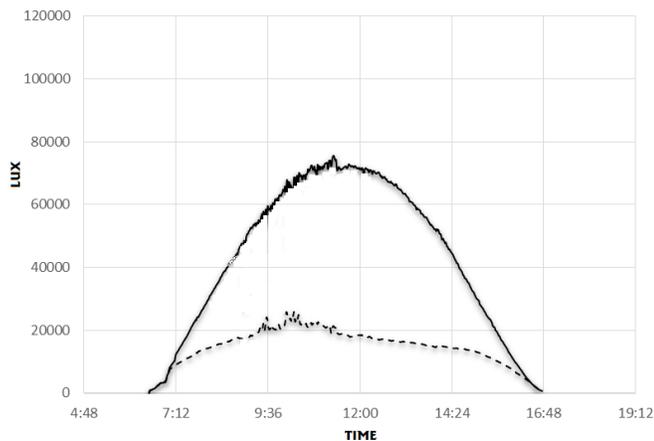


Fig. 4 Global and diffuse horizontal illuminance (21 Decemcer).

Figures 3 and 4 presents diffuse and global illuminance for two days, 21 June and 21 Dec. It clear from the figures that illuminance from daylight could reach up to 115000 lux. Such large amount need to dealt in the right way. Due to the need for protection from sunlight in such area, reflected global light should be consider as a main lighting source.

#### A. Direct and Sunlight

The amount of sunlight reaching a surface is affected by the geometrical relationship between the sun and the surface. With the exception of the two periods just after sunrise and just before sunset, direct normal illuminance values do not vary greatly during the hours of a particular day at a given location [24].

Direct sunlight in sunny climates is usually high. Illuminance received on an unobstructed horizontal surface directly from the sun can reach up to seven times as high as illuminance from the sky under clear sky conditions.

This fact illustrates the importance of direct sunlight as a major source of natural light in sunny areas.

#### B. Skylight

Cloud cover in tropical arid climates is low. It usually covers less than 30% of the sky dome [27]. Under such a sky, sunlight is intercepted by the molecules of the earth's atmosphere causing the wavelengths of light in the blue portion of the spectrum to be scattered, which produces the characteristic blue color (skylight) of the clear sky [28]. The luminance of such a sky is low and may be insufficiently bright to act as a major source of interior illumination [24].

The clear blue sky produces a far from uniform distribution of brightness. The brightest region of the sky is the zone around the sun. The darkest is the region which is at 90° from the sun in the plane of the solar azimuth [29]. However, in general, the clear sky has a horizon brighter than the zenith [30][31], except at high solar elevation.

The luminance distribution of the clear sky changes almost constantly due to the movement of the sun. However, the average luminance of the sky remains fairly constant throughout the day [24].

#### C. Reflected Light

The sun is the main source of natural light. However, it is not necessarily the case that light reaching room surfaces through a window is directly from it. Sunlight and skylight will be modified and changed in term of quantity and direction before reaching a room surface. In hot arid climates, and when there is a choice between skylight and reflected light, skylight is not the most effective source of natural light. As was mentioned earlier, the luminance of the sky is low, and direct sunlight is not welcome due to problems of heat gain. Reflected sunlight seems to be the optimum option in such regions.

Light sources in this case (sunny regions) are usually the reflecting surfaces of buildings adjacent to the window wall. The sky luminance, compared with the luminance of adjacent surfaces of building and low-lying roofs receiving direct sunlight, is low (except around the sun). The difference may reach a factor of five. The luminance of the clear sky may be 3500-5000 cd/m<sup>2</sup> [32], when the luminance of the sunlit surfaces exceeds 25000 cd/m<sup>2</sup> [33].

It has been shown, for example, in a study by Hopkinson and Petherbridge reported in 1953 on the use of reflected sunlight [34], that under clear sky conditions, the use of such light alone can provide the required illumination level for the whole of the working day.

The amount of light received on any surface is influenced by location of the sun, the geometrical relationship with its surroundings, reflectance of external surfaces and global illuminance.

#### IV. CONCLUSION

Window design is influenced by several factors, particularly, in arid climates, protection from direct solar radiation. Such protection (by the use of shading techniques or by reducing the window area) reduces light from the sky and excludes direct sunlight. Hence, a major source of natural lighting in sunny regions is the reflected sunlight from surrounding surfaces, i.e., ground and external surfaces. Therefore, any method for predicting the internal illuminance in such regions should take

into consideration the importance of the reflected sunlight.

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