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Effects of the splayed window type on daylighting and solar shading

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ABSTRACT

Solar shading is generally considered to be used in hot or similar climates; however in certain climates with high solar radiation and high diurnal temperature variation, solar shading for windows is also necessary. A typical type of shading for this climate is the splayed window. An investigation of the performance of daylighting and solar shading of this window type can benefit the solar shading design for similar climates.

This paper identifies the influencing factors of the splayed window type in daylighting and solar shading and ranks their importance factors via an orthogonal experimental design. Next, the detailed effects of the dimensional factors are investigated for a window of western orientation for a case in Lhasa via a series of simulations using Radiance and Daysim. Afterwards, the performances of this window type in other locations are examined.

The results reveal that the ratio of the exterior and interior window opening areas and orientation have significant influences on the integrated performance in daylighting and solar shading, and the West orientation is identified to be the best for usage of this window type. Similar performances are found in other locations and $R_{DA/SC}$ is found to have a strong positive correlation with the incident solar radiation and the splayed window will be more effective in locations with high incident solar radiation in terms of solar shading and daylighting.

1. Introduction

Window solar shading and its relationship to daylighting performance are often studied. Because solar shading is generally used to reduce cooling loads, it is normally discussed within the context of hot or tropical climates [1–7]; however, in certain climates with high solar radiation and high diurnal temperature variation, solar shading for windows is also necessary, e.g. cold-arid climate. A typical example is the splayed window in traditional Tibetan buildings. This window type is generally used on the first floor of public and residential traditional buildings in Tibet (Fig. 1a) and has reasonable responses to the local cold climate and the high solar radiation. This window type exhibits two main characteristics: first, the size of the external opening is much smaller than that of the internal side, and the width of the external opening can be very narrow; second, such windows are primarily oriented westward, such as the windows of the Jokhang temple (Fig. 1b). This special window form can minimise the amount of incident solar radiation transmitted and spread more daylight to the interior space of a building via the splayed sill and jambs; thus, it can be regarded as a combination of both a natural lighting and solar shading fixture. The features of such window are closely based on the thick exterior walls of traditional Tibetan buildings, the widths of which range from 0.5 m to 0.7 m, and can even reach 1.0 m in certain non-domestic buildings, such as monasteries [8]. In addition, the small exterior opening size can minimise the heat loss through the windows, which is necessary in cold climates. Another advantage of this window type is its ability to provide defence and privacy, which is why such windows are normally located on the first floor. Due to the aforementioned factors, this window type is also used in walls oriented northward and eastward.

In a cold-arid climate with high solar radiation, such as that of Tibet, the low ambient temperature requires that windows feature a small opening area along orientations exhibiting less or unwanted solar gain; however, such a small opening negatively affects the interior daylighting level. Along the West orientation, high solar radiation can cause overheating and damage to a building's interior via ultraviolet rays, even in winter, which accordingly requires solar shading in both summer and winter. Splayed windows in thick walls have been used in Tibet for centuries and represent a typical

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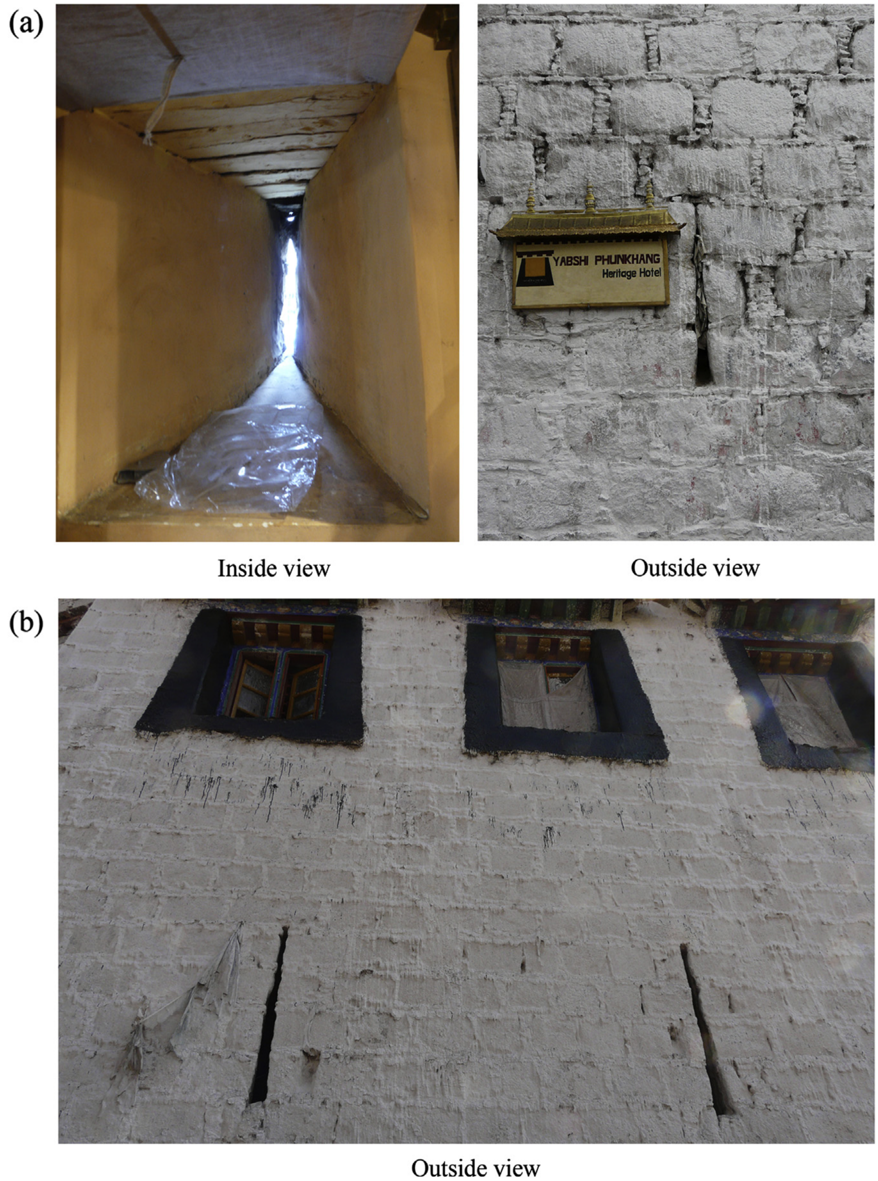

Fig. 1. The splayed windows in Tibetan traditional buildings. (a) Inside and outside view of a splayed window in a typical residential building in Lhasa. (b) Outside view of a splayed window along the western orientation of the Jokhang temple.

climate responsive design strategy. In addition, this window type is still used in current low-cost, low-carbon adobe building designs in similar climates, e.g., the Maosi Ecological Demonstration Primary School (2009 RIBA International Award) in the Gansu Province of China, in which the interior window openings are enlarged to provide more natural lighting [9]. Splayed window on thick wall is also considered as a design strategy to reduce glare-inducing contrast between the window and the adjacent wall [10]. However, the quantitative and scientific understanding of the performance of such windows with respect to daylighting and solar shading are still lacking, which restricts the effective use of this window type in modern passive design. Thus, the key factors affecting the lighting and shading performance of this window type should be determined and investigated, and the daylighting performance along various dimensions should be examined to understand the daylighting features and to benefit green building design.

Window systems regarding solar shading, natural lighting, and energy consumption in aspects of climate and orientation etc. have been systematically investigated [11]. Recent studies have also focused on the impacts on the daylighting and shading performance of various types of solar shades.

A perforated solar screen, a traditional external solar shading element, has been discussed for use in hot, arid desert environments, and the perforation percentage and its effects on illuminance have been studied; these previous studies have indicated that the performance of a perforated solar screen is closely related to the orientation of the window the screen covers and the time of day. The perforation percentage also affects the percentage of annual daylight autonomy obtained [6,7]. Four types of solar shades were studied in a tropical climate with a high relative humidity, and simple indices describing the thermal and visual efficiency of the shades were developed and compared; the number of louver blades and the dimensions of the overhangs were identified for the