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The influence of well geometry on the daylight performance of atrium adjoining spaces: A parametric study

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ABSTRACT

The aim of present study is to assess the impact of atrium width and clerestory height on amount of Average Daylight Factor (ADF) in different floors of vertical top-lit atria and determining the appropriate geometrical sizes for the four-storey, four-sided atrium to provide sufficient daylight in office spaces. The ADF_s predicted using the modelling software IES-Radiance are validated by scale model measurements. Study on the relationship between atrium width (W) and daylight availability in the adjoining spaces of atrium indicates that, the variations trend of ADF in the different floors of atrium are not similar; as the maximum ADF occurs when the width of atrium provides an optimum distance between the office rooms in each floor and the clerestory opening; this distance is significantly related to the sky view angle, altitude angle and optimum distance that daylight can penetrate in the office rooms. Furthermore, it is found that growing the height of clerestory windows increases the amount of ADF in the atrium and its adjoining spaces. It concluded that the minimum acceptable ratio of clerestory height (h) to atrium height (H) for providing the sufficient level of ADF in the atrium adjacent spaces is $h/H=3/8$.

1. Introduction

Buildings sector is responsible for at least 40% of energy use in most countries worldwide [1]. The typical energy breakdown in Malaysian office buildings is 50% for air conditioning, 25% for artificial lighting and 25% for office equipments [2]. Air conditioning energy consumption is not only due to heat from solar gain in the building, but also due to heat from electrical lighting. It means that electrical lighting has a major contribution to increase energy consumption in Malaysia's office buildings. Daylighting is capable for reducing cooling costs when it replaces artificial lighting [3,4]; because daylight produces less heat per unit of illumination than artificial lights [5]. Thus, daylight has become a commonly used design strategy for better building performance [6]. In addition, using daylight as part of an integrated and controlled lighting strategy is a key component of a sustainable, environmental approach to architectural design. Daylight not only reducing energy consumption in the buildings, but also provides a healthy and enhancing visual performance for the users [7–9].

The use of daylight by an atrium is one of the best ways to enhance energy efficiency in the buildings. Atrium improves the indoor environment against external harsh conditions [10]. This form not only is energy efficient, but also is successful in organising the adjoining spaces. Moreover, the atrium is a place for social activities with aesthetic and iconic features [11,12]; but the most important benefit of an atrium is in allowing natural daylight to penetrate into the core of a building [13].

The potential of an atrium to save lighting energy relies on the ability of daylight from the atrium well to displace or reduce artificial lighting in the adjoining spaces of atrium [14]. The daylight potential within the atrium space is generally sufficiently high; while, atrium buildings are often unable to successfully utilise daylight in the adjoining spaces of atrium [12]. The quantity and quality of natural lighting in the adjoining spaces of an atrium are dictated by two main elements include interior and exterior environment [14]. Review the literature have shown the most important interior elements which have effect on the amount of daylight in the adjacent spaces of atria are: (1) atrium roof system and its fenestrations, (2) type, shape, orientation and geometry of atrium well, (3) atrium's enclosing surfaces includes atrium facade design walls and floor reflectances and (4) characteristics of

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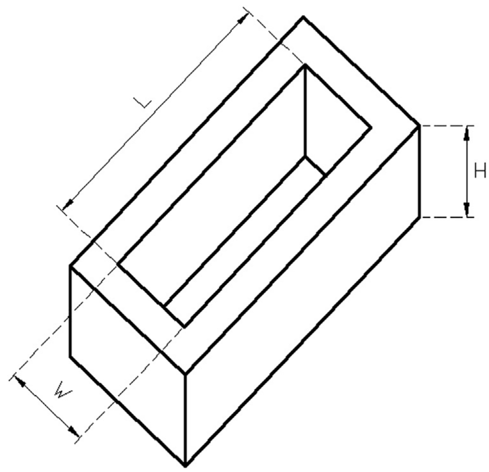

Fig. 1. The main geometric parameters of a four-sided atrium.

adjoining spaces consist of size, surfaces reflectances and so on [15–17]. The type, shape and atrium geometry are very important parameters which have a direct influence on the level of daylight illuminance in atrium and its adjoining spaces [18]. The absolute dimensions of a four-sided atrium can be described by its length (*L*), width (*W*) and height (*H*) as shown in Fig. 1. There are several researches which have investigated the effect of atrium geometric parameters on the daylighting performances in enclosed top-lit atria and their adjoining spaces [19–25]. The summary of findings of many of these researches have shown that in atria with fixed section of well, by increasing the length of atrium, the amount of daylight increases but is unevenly distributed across its width. In addition, by increasing the level of atrium width, the amount of daylight illuminance in the atrium and its adjacent spaces have increased, this event is very logical; because when the atrium width grows the area of top aperture and consequently the amount of sky view from atrium floor and atrium adjoining spaces increases.

Most of the previous studies on daylighting in atrium buildings have been conducted in temperate climates or for regions of northern latitudes. In general, research in atria in latitudes closer to the equator and especially in tropical regions are much fewer, particularly with regard to the daylight performance in the adjoining spaces of atrium. Previous field surveys by Ahmad [26] and Yunus et al. [27] showed that the popular form of atrium in Malaysia is horizontal top-lit with large glazed roof. This type of glazing for atrium buildings poses a challenge to architects designing for the hot and humid regions. In general, the major problem of the existing atrium in hot humid tropical regions is the conflict between the daylight and cooling loads due to large areas of glazing cover and large volume of the atrium space [28]. In these regions, solar radiation penetrating through the large glazed envelope can severely worsen indoor thermal environment of a building during the occupied hours [29,30]. In tropical areas, it suggested by several researchers that the use of sidelight glazing (vertical or clerestory fenestration) is a good strategy to solve this problem. It avoids direct sunlight, minimise cooling load and daylight levels within the atrium floor space are generally sufficiently high [15,31] (Fig. 2). The only study on daylight performance in atrium building in vertical top-lit atria with clerestory was conducted by Ahmad [26], in the tropics; this study focused on the daylight distribution within the atrium space, as the daylight performance of the adjoining spaces of the atrium were not evaluated. The review of literatures showed that the daylight performance in the adjoining spaces of a vertical top-lit atrium has not been investigated until now. Therefore, it is essential to be carried out comprehensive studies on the daylight performance of rooms in atria with vertical top-lit form as an essential and energy-efficient form of atria in tropical regions.

Present research aims to assess the daylight performance in the adjacent spaces of vertical top-lit atrium under overcast sky condition in hot humid region with reference to Malaysia. To this end, the level of effectiveness of atrium geometric parameters for improving the ADF in the adjoining spaces of vertical top-lit atrium of office buildings is investigated. According to Standard Malaysia the recommended range of Average Daylight Factor in office rooms is between 1.0% and 3.5% [32]; thus this paper examines atria with different geometries in terms of width (*W*) and height of clerestory (h) to determine an optimum size for well to provide sufficient ADF in the adjacent office spaces of atrium. Radiance under IES ⟨VE⟩ are used in the calculations of ADF. Firstly, a comparison between physical model measurements and IES-Radiance simulations is undertaken to validate the basic Radiance outputs. Next, more IES-Radiance simulations are carried out to display the impact of well geometric parameters on the amounts of ADF in the office rooms.

2. Methodology

This research employs computer simulation method to experiment the daylight performance in the adjoining spaces of vertical top-lit atrium in Malaysian office building. Prior to that, assessment of simulation tool is carried out by physical scale model method. Therefore, a base case model of vertical top-lit atrium derived from previous literatures of Malaysian atrium office buildings was constructed for providing information on daylight performance in the adjoining spaces of atrium. Data obtained from measurements are analysed and then compared with the

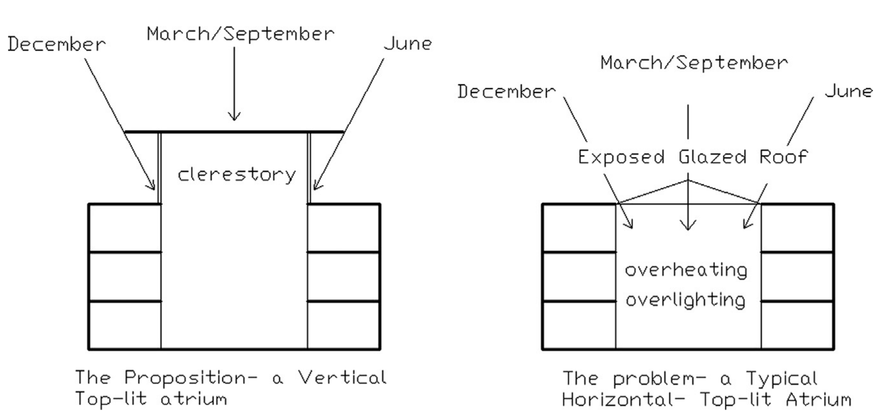

Fig. 2. Horizontal top-lit (right) and vertical top-lit (left) atrium in tropical regions.