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The Impact of Courtyard parameters on its shading level

An experimental study in Baghdad, Iraq

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Abstract

The courtyard pattern has been advocated to be thermally efficient for the hot-arid climatic zone. This paper investigates one of its environmental strategies: shading. By taking Baghdad as a case study, it presents an experimental study, using LightUp Analytics simulation tool, to determine the impact of courtyard geometry and orientation on its shading. The results showed that they significantly affect the shading level. The most effective parameter is the ratio of courtyard width to height. Depending on the results, this paper suggests a regression equation that can predict the shading level of different courtyard forms throughout the year in Baghdad.

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Keywords: Baghdad; Courtyard; LightUp Analytics; shading; simulation.

1. Introduction

The courtyard pattern has been used in most of the hot regions in the world for centuries [1, 2, 3]. But, in most of these regions, it has been replaced since the middle of the 20th century with other modern patterns, such as the detached and row housing patterns, for different reasons. Currently, many studies advocate readopting the courtyard pattern in the current and future buildings in the hot climatic zone for being more climatically responsive and energy efficient than modern patterns. Among these studies are Foruzanmehr [4], Miller et al [5], Ratti et al [6], Manioğlu et al[7], Al Jawadi [8], Soflaei et al [9] and Al-Masri et al [10]. These studies demonstrated the efficient environmental performance of this architectural pattern.

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For instance, Manioğlu et al [7] study presented an experiment showing that in one of the hot summer days in Turkey, the temperature in a courtyard house's room was 22Cº, while in a similar room in a modern western pattern house; it can reach around 33Cº. Al Jawadi [8] study showed that the temperature in a courtyard house in Baghdad can be less by around 9º than the outside temperature. Al-Masri et al [10] compared the energy consumption in a multi-storey courtyard building and a normally closed one in the UAE. The result showed that the courtyard building consumes 6.9% less energy than the other building.

However, studies have shown that to get this efficiency, various factors and parameters should be considered and determined. Otherwise, the courtyard will have negative performance. For instance, Ratti et al [6] study showed that changing the proportions, like the building volume to surface ratio or the courtyard depth, can lead to poor thermal performance. El-deep et al [11] showed that if the courtyard building is situated in a context where it is exposed to the solar radiation from all its sides, its energy consumption will by higher by up to 15% than a similar rectangular non-courtyard building.

Accordingly, to have efficient performance, courtyard buildings should be designed depending on the comprehensive understanding of the courtyard pattern environmental strategies, elements and affecting factors. Basically, the courtyard pattern thermal performance depends on two integrally working strategies: protecting buildings from solar radiation, which includes shading, and natural ventilation [12, 13]. The former implies handling the direct surfaces exposure to the solar radiation to control the heat gain. In summer, the aim is to increase shading to reduce the heat gain and as a result reducing the temperature. While in winter, the aim is to increase the heat gain [14, 13, 9, 15]. On the other hand, natural ventilation helps to reduce the temperature through replacing the hot air with cold one and cooling the building elements. The integrity is implied in that having sufficient natural ventilation is partially related to the first approach as it depends on the pressure differences between the sunny and shaded areas to generate air movement [16, 17]. During the daytime, courtyard buildings are protected from the solar radiation by being attached to the surrounding building blocks [18]. The courtyard, on the other hand, is kept cold, for a specific period, by being shaded. After that, the temperature increases gradually as the solar radiation hits its surfaces. In the night time, the courtyard surfaces radiate their stored energy to the sky [8, 17] and natural ventilation is stimulated by the pressure difference between the hot courtyard and surrounding spaces and the cold outside. The courtyard, at this time, works as a passage for the hot air to be discharged and replaced by cold air. This mechanism helps to reduce the whole building temperature during the night until it reaches its minimum value by sunrise [8,19, 20].

To achieve this performance, a number of elements have been used in the traditional courtyard houses. These elements include, mainly, the courtyard, the wind-catcher, the thick envelope walls, the compact urban fabric and plants and water elements (Fig 1) [21, 17, 8]. Each element has several parameters that affect buildings thermal conditions. Among the main affective factors are the courtyard geometry and orientation, the building volume to external surfaces area, the internal spaces' dimensions, openings size and location and urban compactness (Table1).

Table 1. The main affective factors on courtyard buildings performance

Buildings' elements or features	The effective parameters	The direct impact	Reference
The courtyard	Geometrical properties (Width, length and height) Orientation (the orientation of the courtyard long axis)	Heat gain and natural ventilation	[14, 22]
The internal spaces	Openings size and location The internal dimensions (width, length and height)	Natural ventilation	[3, 23]
The wind - catcher	Orientation and geometrical properties	Natural ventilation	[24, 25]
The building envelope	Envelop thermal mass (construction materials U-value)	Heat gain	[3,7]
The water& planting elements	The ratio of these elements area to the courtyard area	Heat gain and natural ventilation	[9]
The building form	Building volume to external surfaces area	Heat gain	[1]
The building urban context	Building adjutancy and urban fabric compactness	Heat gain and natural ventilation	[3,21]

This research focuses on the impact of changing the courtyard parameters on its shading for its significant impact on the courtyard and the surrounding spaces thermal conditions; having a larger shaded area for a longer time, in summer, can significantly help in improving the courtyard building thermal performance. It helps to have a cooler courtyard for a longer period during the daytime with less heat storage, and reduces surfaces heat radiation during the night time, which might lead to having overall less temperature in the whole building. However, the research