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The impact of courtyard compact urban fabric on its shading: case study of Mosul city, Iraq

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Abstract

The courtyard pattern provides a comfortable environment in hot regions through supporting natural ventilation and protecting buildings from solar radiation. But, its performance depends on its urban fabric compactness as it affects surfaces' heat gain resulted from the solar radiation. The impact of urban compactness on urban shading is tested by simulating traditional compact and modern less compact neighborhoods in Mosul. Results from two sunlight simulation systems, Autodesk 3DS Max 2014 and LightUp Analytics, demonstrated that courtyard neighborhoods are nearly three times more compact than the modern neighborhoods. This leads to having five times larger shaded area, which helps to offer a more thermally comfortable environment.

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1. Introduction

The courtyard pattern is one of the oldest architectural forms. It had been used in hot regions around the world since the first old civilizations in Mesopotamia, Egypt, India and China until the middle of the last century [1, 2, 3, 4]. It includes having an open space in the building's core, which provides natural lighting and ventilation for the surrounding spaces, regulates the thermal conditions, and offers a private open space for occupants' interaction and activities [1, 4]. However, for various reasons, such as the development of the construction materials, the changing of the architectural styles, and the social, cultural and political changes [5,6], it has been replaced with new patterns

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of buildings, such as the detached and semi-detached buildings, which depend mainly on the electrical air-conditioning to provide a comfortable indoor environment. This has led to increasing the running costs, the energy consumption and buildings' negative impact on the environment [7]. Aiming at having more climatically, environmentally and economic buildings, many studies have investigated the thermal performance of the courtyard pattern in hot regions. Depending on their results, they have advocated readopting the courtyard pattern for being a thermally efficient solution for the hot climate [8, 9, 10].

The courtyard climatic efficient performance depends on using a number of elements including the courtyard, the wind-catchers, the thick walls and the basement [9, 11, 12]. They all work to apply two main environmental strategies: providing sufficient natural ventilation [13] and managing buildings exposure to the solar radiation, which includes providing shading [14]. The latter reduces heat gain, while the former helps to reduce the temperature [12, 15]. But, it is suggested that courtyard buildings might lose their thermal efficiency by being situated out of the traditional compact urban fabric, as they will have more exposed surfaces to the solar radiation and, as a result, get more heat gain [16]. For instance, as a detached building in a modern urban fabric, courtyard buildings might have an extra heat gain of up to 15% comparing with a square non-courtyard building of similar area [17]. Furthermore, it has been argued that urban compactness affects the whole urban fabric temperature, not just buildings, by increasing urban shading [12]. However, it has not been stated to which extent the proposed thermally efficient traditional compact urban fabric can increase the urban shading comparing with the new modern less compact urban fabric. Aiming at demonstrating this aspect and defining a thermally efficient built environment for the hot climate, this study focuses on determining the impact of urban fabric compactness on urban shading for its impact on the whole urban fabric thermal conditions. It analyzes a traditional compact urban fabric and a modern less compact one to show how a higher level of compactness can lead to a higher level of shading, which in turn helps to reduce the heat gain and to have a thermally comfortable environment.

2. Research aim and methodology

Aiming at analyzing the efficient thermal performance of the traditional compact urban fabric to be used in the future to develop a thermally efficient urban environment, this research determines the impact of urban fabric compactness on urban shading as it has a significant impact on buildings and urban temperature. To achieve this aim, the study adopted the experimental research method, as it is the research method that can help to analyze and determine variables' causal relationships. Mosul city in Iraq was selected as a case study; it has a hot climate and traditional compact and modern less compact urban fabrics. The experiment included doing a shading simulation for two neighborhoods in Mosul: a compact traditional neighborhood and modern grid-iron less compact one. Two simulation tools were used for the simulation purpose to have more integrated and confident results: LightUp Analytics and Autodesk 3D Max 2014. Both of them provide comprehensive simulation results depending on validated sunlight simulation systems. They simulate buildings shading with considering the correct sun angles and movement for simulation time, date and geographical location [18, 10, 20]. The measured indicators in the simulation included the compactness level and shading percentage and time in each of the two neighborhoods. The results included demonstrating how their compactness levels affect their shading.

3. Determining the impact of urban fabric compactness on shading

Two neighborhoods, a traditional compact one and modern grid-iron less compact one, from Mosul city, were selected and modeled based on Google map (Fig. 1). The former is located in the old part of the city where courtyard buildings are attached to each other to form a compact urban fabric. The latter is located in the modern part of the city on the western bank of Tigris River. Buildings are of the modern patterns like the detached, semi-detached and row houses. In both of the two neighborhoods, buildings' height was assumed to be of two floors with a total height ranges between 7.5m to 8.0m, which is the most widespread height of residential buildings in Iraq, including Mosul [21, 22].

To simulate the shading, 3DS MAX 2014 and LightUp Analytics software were used, to get more comprehensive results. Using the 'Sunlight' function and the 'Daily sunlight' option in 3DS MAX 2014 and LightUp Analytics

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