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The Influence of Urban Geometry on Thermal Comfort and Energy Consumption in Residential Building of Hot Arid Climate, Assiut, Egypt

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Abstract

Designing climatically responsive dwellings not only can achieve thermal comfort for occupants, but also can make a significant improvement in energy conservation. Consequently, interest in the microclimate around buildings in urban areas has increased because its affects other things; outdoor and indoor thermal comfort, energy consumption in heating and cooling, and the spreading of air pollution. This paper aims to investigate the influence of open spaces (outer courtyards) between building "Shallow canyons" with a H/W ratio of 0.24~0.6 in one of the urban patterns of youth housing sectors in New Assiut city and deep canyons with a H/W ratio of 4 in one of the new residential houses (El-Abrahimia and El-Moalemen complexes) in the center of Assiut city on indoor thermal comfort. A comparison was made between the two cases based on indoor thermal comfort, energy consumption and IAQ in hot arid climate.

The study shows a decrease of indoor temperature inside living rooms that overlook the deep canyons in El-Abrahimia complex with a difference of 11°C from the outdoor in the hottest day of July. The design of deep canyons causes a temperature decrease of 6~9.4°C compared to outdoor temperature in different points of the courtyard. Indoor temperature in these cases reach the upper limit of 90% acceptable range of ASHRAE during July with a maximum indoor temperature 32.5°C based on the strategy of using natural ventilation. The findings show decreases of cooling demand and energy consumption in deep canyons. This is considered a basic monitoring method that could be used in the future strategy of sustainable housing design of new cities in hot arid climate.

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Keywords: Urban geometry; Thermal comfort; Indoor temperature; Indoor CO_2 concentration.

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1. Introduction

Climate has a major effect on the performance of buildings and their energy consumption. The variation of temperatures across residential densities in urban areas and its effect on indoor thermal comfort will be taken as an index of the impact of the urban microclimate on the built environment in cities [1]. Compact urban forms in hot dry regions typically found in old city centers are known to be well adapted to the climate [2]. There are, however, few studies from hot dry climates on urban microclimate [3]. In addition, revitalizing outdoor spaces will lead to energy savings inside buildings.

El-Deeb et al. studied the effect of building form and urban pattern on the energy consumption of air-conditioned buildings in different desert environments. Energy simulation was performed for three desert cities: Jeddah (Saudi Arabia), Cairo (Egypt) and Alexandria (Egypt) [4]. Kruger et al. observed and estimated relations between urban morphology and changes in microclimate and air quality within a city center. Two approaches are presented, showing results of field measurements and urban climate simulations. From measured microclimatic data and comfort surveys, carried out in downtown Curitiba, Brazil, the impact of street geometry on ambient temperatures and on daytime pedestrian comfort levels was evaluated [5]. Dalman and Salleh investigated the microclimatic principals of two different fabrics in South East of Bandar Abbas using different thermal comfort indices and microclimate assessment of residential urban canyons and focused on effect of vegetation, building environment & shading [6]. Taleghani et al investigated the effect of courtyards, atria and sunspaces on indoor thermal comfort and energy consumption for heating and cooling. Four building types were modelled and simulated in three different climates using Design Builder [7]. Literature showed that the quantitative analysis for the impact of building and urban forms, orientation, and passive treatments as shading and insulation on indoor energy consumption and indoor thermal comfort in desert environments are not sufficiently addressed and need more investigation concerning physical measurement and indoor and outdoor monitoring. Desert environments are classified as hot-arid desert according to Köppen-Geiger climate classification. However, there are differences between desert environments regards to temperature and humidity ranges despite being of the same classification.

The aim of this paper is to investigate the influence of open spaces dimension (outer court-yards) between buildings "Shallow canyons" with a H/W ratio of 0.24~0.6 in one of the urban patterns of Youth housing sectors in New Assiut city and deep canyons with a H/W ratio of 4 in one of the new residential house (El-Abrahimia and El-Moalemen complexes) in the center of Assiut city on indoor thermal comfort and energy consumption in hot arid climate. The dependence of urban geometry design on indoor condition was emphasized in order to evaluate two different urban canyons on indoor comfort and energy for future design strategies of sustainable city in hot aird climate.box

2. Methodology

Investigation was done in the living rooms of four different flats facing the open urban space with different orientations in New Assiut city, and four points in different locations of the building facing the outer courtyard "deep canyons". The middle floor of Youth housing sector was chosen, and is occupied by average four occupants. This was seleted in order not to be affected by high solar radiation in the top floor or heat transfer from the ground floor. The air temperature, humidity, and CO_2 were measured using data loggers- Thermo Recorder model TR72Ui with measuring accuracy: ±1%RH, ±0.1°C and TR-76Ui with measurement accuracy ± (50 ppm + 5 % of reading), ±0.5 °C and ±5 %RH and measurement range 0 to 5,000 ppm, 0 to 45 °C, 10 to 90 %RH. Also, four points in different locations of the El-Abrahimia building were chosen facing the outer courtyard "deep canyons". The datalogger was placed in the living rooms of different flats. Four locations were chosen (end point, middle point, outer point of courtyard, and outside street location). Investigation was carried out during the summer season; July, August, and September, 2014. Also, temperature measurements were conducted inside the outer courtyard deep canyons in the hottest day of June (1pm~pm) and measurement of 15 points inside the courtyard with relation to outdoor temperature. All outdoor data was measured with TR72Ui in the Assiut and New Assiut city to compare indoor and outdoor measurements at the same period and location. Outdoor wind speed is measured inside outer courtyards by hot wire anemometer model AM-4214SD with accuracy ± (5% + 0.1m/s). The research compares the