EVALUATING THE SHAPING OF PEDESTRIAN STREETS OF ROW HOUSES IN FAYUM DESERT VILLAGE IN EGYPT AS A CASE STUDY

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ABSTRACT

Because air flow is required in hot climates, even when the air temperature is reaching 40^{o} C, in order to reduce the thermal stress for pedestrians and reduce their sweat under the intensive solar radiation during the overheated period (Givoni B. 1998) [1]. And the theoretical studies of Golany, G. (1980) [2], show that zigzag streets enhance air flow through the compact urban pattern, where air pressure and air vortex spread by the edges of buildings' blocks and enhance the air flow that decreases air temperature in pedestrian streets. Thus, The paper presents field measurements -using a thermos-anemometer- for air temperature and velocity through traditional and formal row houses urban pattern, in order to measure the effect of urban morphology – staggered blocks, zigzag streets and orientation – in achieving air flow and air temperature at the pedestrian level. Also, numerical simulation (using Ansys software program) was done to verify the effect of zigzag streets that are located at the wind shadow area in activating air flow through the row house urban pattern. Measurements have been in Fayum Oasis (latitude 29 ^{o} N), in which there is calm and a hot air flow pattern. Results proved that zigzag streets activate the air flow through the row house fabric in general, and through the wind shadow area by about 10-50 % of the local free wind speed.

~~KEYWORDS~~: Row houses urban pattern; Narrow bended street; Zigzag street; CFD (Computational Fluid Dynamic).

الملخص

لأن تدفق الهواء مطلوب في المناخ الحار حتى عند درجة حرارة للهواء تبلغ ٤٠ درجة مئوية، وذلك من أجل الحد من الإجهاد الحراري للمشاة والحد من العرق تحت أشعة الشمس المكثفة خلال فترة الذروة الحرارية [جيفوني ١٩٩٨]. وتظهر الدراسات النظرية لجولاني (1980) أن الشوارع المتعرجة تعزز تدفق الهواء من خلال نمط النسيج العمراني المتضام، حيث يتم تشتيت وانتشار ضغط الهواء والدوامات الهوائية بواسطة حواف كتل المباني فينشط تدفق الهواء وتقل درجة حرارته خلال تلك الشوارع الضيقة. وهكذا، تقدم هذه الورقة التحقق لتلك الدراسة النظرية من خلال دراسة عملية وقياس حقلي لسرعة ودرجة حرارة الهواء خلال نمط النسيج العمراني المتضام، من أجل قياس تأثير نمط التشكيل العمراني المتضام - كتل متداخلة، وشوارع متعرجة - في تنشيط تدفق الهواء و خفض درجة حرارته عند مستوى المشاة. أيضا تم عمل محاكاة رقمية باستخدام برنامج الحاسب الالي (Ansys) للتحقق من تأثير الشوارع المتعرجة ضمن النسيج المتضام والتي تقع في منطقة ظل الرياح في تنشيط تدفق الهواء خلالها. وكانت القياسات في واحة الفيوم (خط العرض ٢٩^{o} شمال) خلال فترة الذروة الحرارية. وقد أثبتت النتائج العملية للمحاكاة أن الشوارع المتعرجة تعمل على تنشيط تدفق الهواء بالنسيج المتضام للمباني الشريطية الواقعة في منطقة ظل الرياح بنحو ١٠-٣٠٪ من سرعة الرياح الحرة المحلية، حيث يزيد التدفق قرب التقاطعات وعند احرف المباني، وانه بزيادة احتواء المسار الواقع في منطقة ظل الرياح تزيد سرعة الهواء وتقل حرارته، وهو ما اثبتته نتائج القياس الحقلي بالنمط العمراني للمباني المصفوفة بقرية تونس الفيوم ذات مباني بارتفاع دورين وشوارع متعرجة بعرض ٦ متر ونسبة قطاع ١، فكانت السرعة ٥٠% من السرعة الحرة وهي ١,٥م/ث وانخفضت الحرارة درجة عن حرارة الهواء اعلى المبنى، بينما بقرية الطلائع ذات مباني بارتفاع دور واحد ونسبة قطاع ٠,٥ وبنفس عرض المسار ٦ متر، كانت السرعة ٧% من السرعة الحرة ولم تنخفض درجة حرارة الهواء بالمسار عن حرارة الهواء الحر.

INTRODUCTION

Givoni, B. (1998) [1] supposed that the air velocity does not increase by increasing the width of space between buildings which are perpendicular to the wind direction, that is because space is located in the wind shadow area, while the narrow streets enhance air flow because they act as tunnels and activate the air flow. Fernando M. and Jorge G. (2005) [3] estimated natural ventilation flow rates around buildings. The principle was to assume that the flow paths are known and that the whole building is an association of ducts that can be coupled either as series or parallel configurations. The equivalent characteristic airflow pressure curve is then established. The main driving force is the pressure difference on façades, expressed via their respective pressure coefficients, together with an appropriate reference wind velocity. The wind tunnel experiment proves that wind velocity behind the building (leeward) does not exceed 20-40% of the wind velocity in front of the building (windward) [4]. A numerical simulation study for streets that are perpendicular to the wind direction, with long row house buildings. The streets' widths are 6m, 12m, 22m, and the height of the surrounding buildings are 18m, so the ratios of the streets (height /width) are 3, 1.5 and 0.8. Wind velocity increases by 170% (of the local wind velocity in front of the row house buildings) in the narrow street (ratio 3), the narrow street acts as a tunnel and enhanced the wind flow though the compact urban pattern [5]. Numerical simulation studies the effect of isolated and row house urban pattern on the air velocity and temperature during the overheated period in Minia (latitude 28°N). The row house is perpendicular to the wind direction and the distance between buildings is equal to 1.5 the depth of the building; air velocity decreases and temperature decreases by 2-3°C than in the isolated urban pattern [6]. A numerical simulation study detects the effects of building arrangement - point and slab blocks with the same height and site coverage, and streets average ratios 3.7- on outdoor thermal conditions and building, the results show that the building with point shape shows more potentials of saving energy and the slab blocks arranged parallel form wind channels which can benefit the urban ventilations [7].

1. FIELD STUDY

The field study is carried for the traditional and modern urban pattern- row houses- of residential projects in Fayum Oasis (latitude 29 °N), which suffers from severe solar radiation and hot dry air during over heated period. The experimental field measurements of air velocity and temperature in the pedestrian street models of formal and traditional housing projects in Fayum experimented the effect of narrow zigzag streets, orientation and layout natural features on modifying the urban climate in both traditional and contemporary (formal) row houses urban pattern.

2.1. Models' Description

Urban pattern models are described in the Tables 1, 2 and Figs. 1, 2.

Fig.1. formal row house urban pattern in Fayum Oasis – Al-Tala'i` village; (A) Main street; (B) Mass housing; (C) house inner court. [Author]

Fig. 2. Tunis village in Fayum Oasis: (A) layout of row-house urban pattern; (B) Main street; (C) Housing mass; (D) Back house courtyard. [Author]

Table 1. Urban features in traditional urban pattern

formal urban pattern- Al-Tala'i` village	
Urban features	Row houses, straight streets
Buildings envelope	12 cm brick walls and 10 cm concrete roof with thermal isolation
Court of the house	Exposed corner side court
Building Height	3 m
Residential street width	10 m
Residential street distance	300 m
street ratio (h/w)	0.3
street orientation	N/S, W/E
Street begins – ends	Begins and ends with asphalt streets (12m width), desert surrounds the site

Table 2 Urban features in traditional urban pattern

Traditional urban pattern - Tunis village	
Urban feature	Compact row house fabric and bended street
Buildings envelope	50 cm white stone and brick walls and 25 cm vaulted brick roofs
Court of the house	Simi-shaded front south court and back garden oriented to north

Building Height	6-8 m
Residential street width	3- 6 m / oriented south to north
Residential street distance	300 m / oriented east to west
Residential street ratio (h/w)	Average 2 , 1.5
Residential street orientation	N/S, W/E
Residential street begins – ends	begins and ends with the same asphalt street (12m width), narrow paths (3m width) are every 100 m, and perpendicular to the main street. Paths are sloping towards the north and the palm orchards.

2.2. Measuring Conditions and Observation

A digital thermo-anemometer records the air velocity and temperature. Wind direction is determined by long band of muslin or smoke of incense bar. It should be taken into account that the wind rotary device is perpendicular to the direction of movement of the air to measure the maximum movement of air, and the rotary sensor (to measure the air temperature) is in the shade.

Measuring starts at the main street and is continued along it, and at every intersection. Average readings take at each measuring point 2-3 minutes, every 5 to 10 meters. Measuring level height is 1.9m above the ground at the pedestrians' level.

Measurements is done during the overheated period at 13:00-16:00 pm (May, 2014). The maximum temperature is 30 °C. Prevailing wind direction is at north and north-west in all cases, and the local free wind speed is on the roofs of the houses overlooking the residential streets at 3 m/s, which corresponded with the readings of the main streets.

2.3. Results and Discussion of Field Measurements

2.3.1. Tunis village -Fig. 3A

- Maximum air velocity (3m/s) and minimum air temperature (27°C) are at the narrow street, that is sloping to the north palm orchards. narrow street ratio is 2 (3m width and 6m height).

- Air temperature decreases 1°C in southern spaces and east-west residential street with ratio 1 (6m width) than free wind temperature above row house buildings (30°C).

- Staggered house blocks and zigzag streets with ratio 1and width 6m, enhances air flow at the leeward direction, where the air velocity is 50% of local free wind velocity (average 1.5m/s).

- Indoor air temperature is 2°C less than the outer air temperature (30°C) in the absence of air movement through the inside southern spaces of heavy mass house (50cm stone walls and 25cm brick vaulted roof with 5cm cement plaster).

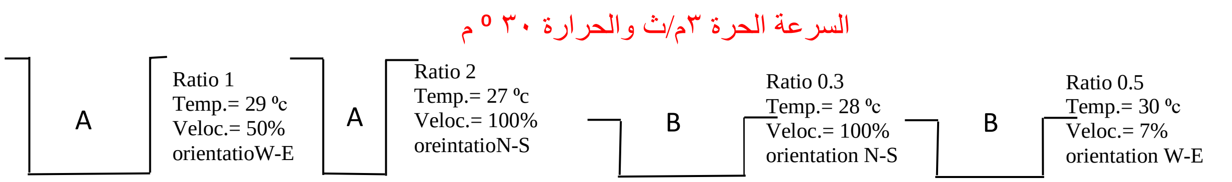
2.3.2. Al-Tala'i` village -Fig. 3B

- Maximum air velocity (3m/s=100% of free air velocity) and minimum air temperature (28°C) are in north south street with ratio 0.3 (10m width) because it is parallel to wind direction and the mutual shade at the street shoulders during the day time.

- Minimum air velocity (7% of free air velocity) and higher air temperature (30°c) at west east street with ratio 0.5, that street is perpendicular to wind direction- at wind shadow area.

- Indoor air temperature decreases 2°C at northern spaces than the outside air temperature, and decreases 0.5°C at western and southern spaces, in absence of air movement. The building is of concrete structure, 12 cm cement brick walls and 10 cm concrete roof with 5 cm thermal insulation and cement tile.

Fig. 3. Section at pedestrian streets: (A) Tunis village, (B) Al-Tala'i village, with value of air temperature, velocity, ratio and orientation (free air velocity 3m/s, temperature 30°c).



3. COMPUTER NUMERICAL SIMULATION

The digital experiment is to verify the effect of zigzag streets that are located at the wind shadow area in activating air flow through the row house urban pattern during the overheated period.

3.1. Computer Program

A software computer package (ANSYS CFD software) [8] is used to investigate the air velocity and temperature distribution inside the test model, in the form of velocity contours and vectors. The program is three dimensional; it utilizes the finite element approach which uses the k-ε turbulence model and solves the Reynolds equations, the energy equation and the equations for turbulence energy and its dissipation.

3.2. Inputs of the Case Study

- Climatic data is for the Upper Egypt region (latitude 29 °N) during the overheated period in May – maximum temperature is 32 °C [9]. Free wind velocity is 7m/s at height of 10 m.

- Experiment's geometrical data
Row house blocks' height is 15 meters, the house unit block is 6×16m, Maximum distance is 100 meters along the pedestrian street, as a medium walking distance. The perpendicular street width is 4-6m (average ratio of height to width 3), and the streets parallel to wind direction are 6m width in middle and other three streets are 8m width (average ratio 2). There are vistas at several positions.
The measuring points are along the axis of the street and at a height of 1.5 m from the surface of the ground level.

3.3 Results of the Simulation

-Results prove that zigzag streets activate the air flow through the row house fabric in general, and through the wind shadow area by about 30-10 % of the free speed, where velocity increased at the narrower street. (Figs. 4,5)

-The maximum air velocity in straight and narrow street (5m average width, ratio 3) that are parallel to the direction of the wind - air velocity is 70% (average 5 m/s) of the free wind speed above building (7 m/s).

-As a result of separation of air current by edges of staggered blocks and multiple intersections, air velocity and air vortex flow increase through the wind shadow area of the streets that are perpendicular to wind direction (4,12m width, ratio 3,1.3), air velocity is 30-10% of local free wind (2-0.7m/s).

-Air velocity at blocks edges are 86% of local free wind (6m/s); that clarify the round edges of traditional houses in oasis in order to avoid the sandy wind erosion of buildings edges.

4. CONCLUSION AND RECOMMENDATIONS

- The existence of narrow and zigzag paths are important in enhancing air movement and decreasing air temperature through the row house urban fabric in general, and through the wind shadow area by about ١٠-٥٠ % of the local free wind speed (fig. 3, fig.5B), where air velocity was 50% of free wind speed (1.5m/s) and air temperature decrease 1^{o}c through street with ratio 1 (width 6m) in Tunis village, while air velocity was 7% of the free wind speed through street with ratio 0.5 (width 6m), and temperature was the same of air temperature above building in Al-Tala'i` village (30^{o}c), (fig. 3). And the near results was at the simulation study where air velocity at zigzag street was 30-10 % of the free wind speed (Figs. 4,5).

-Thermal performance of narrow street is better than the wider street with same orientation that are either parallel or perpendicular to the wind direction.

-Thermal performance of heavy mass building with 50 cm brick walls is better than concrete structure building with 12 cm brick walls.

-Northern agricultural fields adjacent to housing blocks contribute to the reduction of air temperature passing through blocks, while the big canopy trees at pedestrian streets represent an obstacle for airflow in the urban fabric.

Fig.4. the vectors of Air flow pattern through row houses urban pattern.

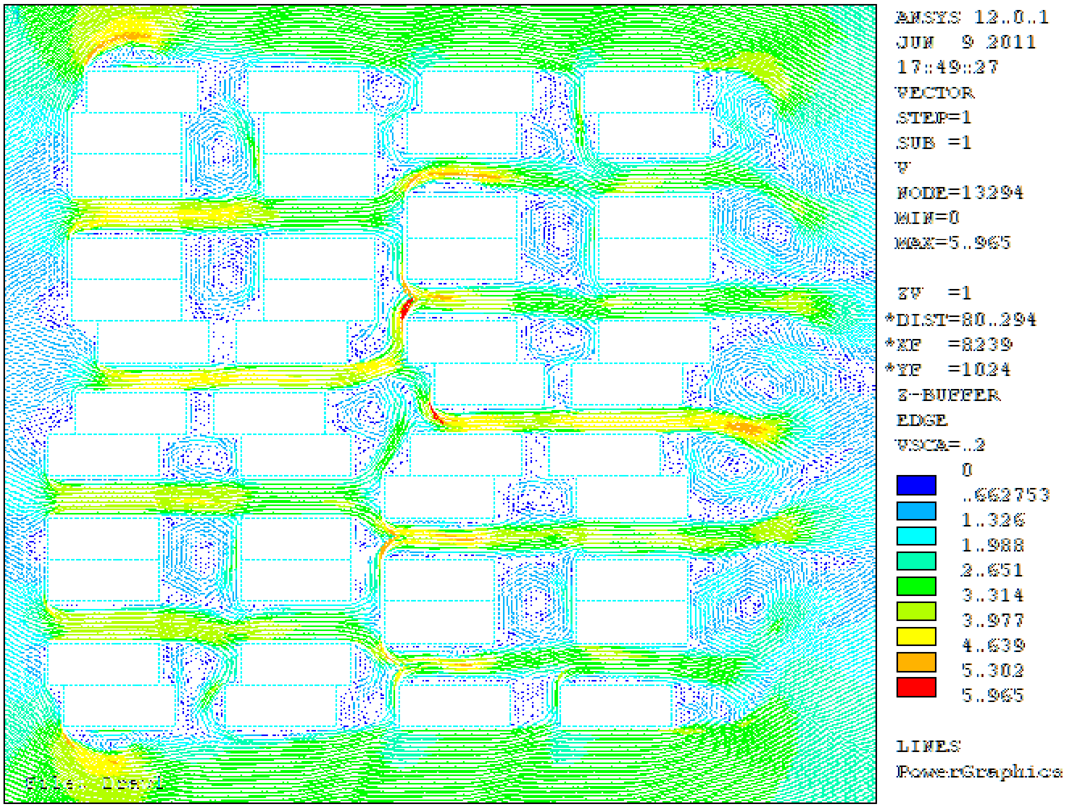


Fig.5. Section at streets with ratios and value of air velocity : (A) street that is parallel to wind direction; (B) street is perpendicular to wind (free air velocity 7m/s).

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