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Effect of Urban Geometry and Spacing on the Thermal Performance in the Mediterranean Climate of the Gaza Strip

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Abstract. This paper studies the thermal performance of different forms of the housing units located in the Mediterranean climate of the Gaza Strip and within different urban configurations. The paper is carried out using the computer programs ECOTECT and IES. The results indicate significant thermal effects due to the urban geometry. The paper concluded that the spacing ratio (L1/L2) equals 0.1 and aspect ratio (H/W) equals 0.5 is the preferable option in the (E-W) street in the Gaza Strip. However, the more preferable option in the (N-S) street has a spacing ratio (L1/L2) equals 1.2, and aspect ratio (H/W) equals 4.0. Therefore, Building's proportions have to be determined with a full understanding to their relations with the urban morphology. It is also recommended to utilize the advantages of the mutual vertical arrangements of building in achieving shading on the roof and building's façades by using different heights of buildings.

Introduction

Buildings clustered with each other's in an urban configurations. Buildings and spaces between them are considered the main determinant of the urban geometry. Building and its plot are an entity in the urban context and cannot be treated in isolation (Goulding *et al.* 1992). Hence, the buildings proportions have a considerable relation with the urban canopy which affects the solar potential and thus the thermal response for the outdoor and indoor environment of the residential blocks. Ratti *et al.* (2005) documented an effect of almost 10% in the relationship between urban morphology and the annual per-meter energy consumption of non-domestic buildings. Strømann-Andersen and Sattrup (2011) found that the geometry of urban canyons has an impact on the total energy consumption in the range of up to +30% for offices and +19% for houses. The geometry of the adjacent buildings plays an important role in the microclimatic conditions in the urban canopy (Shashua-Bar *et al.* 2004). Building height and its relation to the street width which is known as the aspect ratio (H/W) is one of the main factors affecting the urban form and its thermal response. It can affect shading at street level during daytime which has a side effect on nighttime cooling and natural ventilation, as night winds are more restricted with higher aspect ratios (Krüger *et al.* 2010).

There have been some studies to investigate the relation between the urban geometry and the energy performance of the individual buildings. Shashua-Bar *et al.* (2004) studied the thermal effects of the building dimensions and spacing as related to the urban canopy layer (UCL) geometry. The study based on measuring the outdoor diurnal air temperature values for each configuration. The study show significant diurnal variation in the air temperature patterns in the north–south-oriented street among the various building configurations which reach to about 6.8 K. Krüger *et al.* (2010)

examined the effect of different street canyon geometries and orientations on building cooling loads in a dry environment. Ali-Toudert and Mayer (2006) studied the effects of aspect ratio and solar orientation on the outdoor thermal comfort in hot and dry climate. The study concluded that the air temperatures decrease slightly with the increasing the aspect ratio. The thermal environment for wide streets (H/W= 0.5) is highly stressful and almost independent of the orientation. A (N–S) orientation combined with high aspect ratio provides a much better thermal environment.

It is found from all the previous studies that the integration between buildings and urban dimensions have a direct impact on the thermal environment. It affects the amount of solar radiation and adjacent shading either on the buildings façades or the street level. The previous studies focused on the effect of urban geometry on the outdoor thermal comfort in hot climates and during the summer periods. Hence, the effect of these variables on the indoor thermal performance, energy consumption and solar radiation weren't studied. In the Mediterranean climate of the Gaza Strip, both cooling and heating requirements are essential in determining the indoor thermal response of buildings in various urban geometries. So, understanding the relation between the building geometry in the urban fabric and the thermal performance can be obtained from investigating the main aspects, which define the urban form. These integrated parameters are the spacing ratio, the aspect ratio, the width to length ratio and the street orientation.

Simulation Tools

ECOTECT is a software package with a unique approach to conceptual building design. It offers a wide range of internal analysis functions which can be used at any time while modeling. These provide almost instantaneous feedback on parameters such as sun penetration, potential solar gains, thermal performance, internal light levels, reverberation times and even fabric costs (Marsh, 2003). ECOTECT based on the CIBSE steady state methods. This method uses idealized (sinusoidal) weather and thermal response factors (admittance, decrement factor and surface factor) that are based on a 24-hour frequency (Beattie and Ward, 2012).

The <Virtual Environment> is an integrated suite of applications linked by a Common User Interface (CUI) and a single Integrated Data Model (IDM). This means that all the applications have a consistent "look and feel" and that data input for one application can be used by the others. (VE-Pro User Guide - IES Virtual Environment 6.4, 2011). Simulations were performed using the ECOTECT software. Also, the virtual environment (IES) software was used to validate the simulation results and to provide the high quality information... The 3D models were created using *ModelIT*. Then the solar shading analysis was performed using *SunCast*. Finally, a dynamic thermal simulation was carried out using *ApacheSim*. The simulation results were expressed in terms of annual heating loads, annual cooling loads and annual total loads (in MWh).

Simulations were carried out during the months of January–December. Local latitude is 31.08 N, longitude 33.82 E and the elevation is approximately 32 m above sea level. The HVAC system was assumed to be full air conditioning with the heating and cooling set point were assumed to be 18.0^{0}C and 26.0^{0}C respectively. Use of buildings (hours of operation) was assumed to be on continuously. As the study focuses on the incident solar radiation as one of the most important variables in the Mediterranean climate affecting the heating and cooling energy consumption, the internal heat gain from occupancy and appliances as well as the ventilation heat gain weren't considered in the study.

External walls have U-values of 1.77 W/m^2. K in ECOTECT and 1.9487 W/m^2. K in IES. The roof U-values are 0.896 W/m^2. K in ECOTECT and 0.9165 W/m^2. K in IES. Glazing U-values are 6 W/m^2. K in ECOTECT and 5.5617 W/m^2. K in IES. The values of Thermal Transmittance, U-value for walls, roof and floor were assumed to achieved the minimum requirements of the maximum U-values as recommended by the Palestinian code for energy efficient building (2004). See Appendix (1) for details of default settings for the two programs. For solar radiation calculations, ECOTECT uses hourly recorded direct and diffuse radiation data from the weather file.

3. Climate

The Gaza Strip (365 km2) is a coastal area in the west-southern part of Palestine (ARIJ, 2003). The geographical coordinates of the Gaza Strip are

31° North, and 34° East (Ministry of Local Government, 2004). According to ARIJ, (2003) the Gaza Strip forms a transitional zone between the sub-humid coastal zone of Palestine in the north, the semiarid loess plains of the northern Negev Desert in the east and the arid Sinai Desert of Egypt in the south. According to the Koppen system for climatic zoning, Gaza has a Mediterranean subtropical climate with dry summer and mild winters. This climate is classified as C_{sa} indicating that the warmest month has a mean temperature above 22°C. the average daily mean temperature which ranges from 25°C in summer to 13°C in winter (ARIJ, 2003).

The Study Parameters

The study examined the relation between the building geometry, the urban canopy and the thermal performance. It dealt basically with four parameters which are the spacing ratio, the aspect ratio, the width to length ratio and the street orientation, which are considered the most important parameters linking the building's dimensions with the urban geometry. The spacing ratio (L_1 / L_2) can be described as the ratio between the distance between adjacent buildings L_1 and the frontal length of building L_2. The aspect ratio (H/W) is relating the building height H to the width of the street W. the study investigates the effect of these parameters on the cooling, heating and total loads. The simulated cases were chosen to represent the common options in the housing complexes in the Gaza Strip. The floor area (A) was taken to be 500 m^2 and the building height was taken to be 20 m (nearby 6 storey) and thus the volume was taken to be 10000 m^3. The study examined 210 urban blocks with each block consists of 6 buildings and only the central building was considered as shown in (fig. 1). Tables 1 and 2 display the parameter combinations investigated in the study.

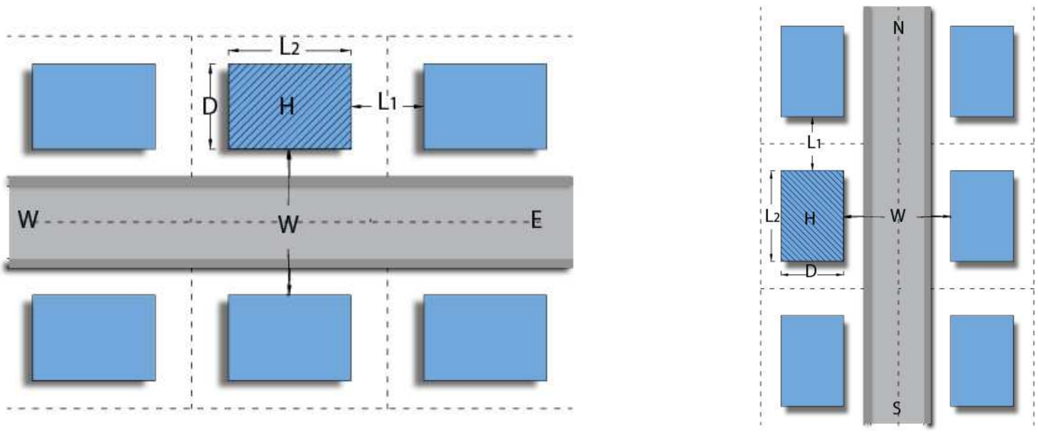


Fig. 1. The generic form of the urban block

Table 1: Parameter combinations investigated in the study

Shape	Spacing Ratio (L1/L2)	Aspect Ratio (H/W)	Width to Length Ratio (D/L2)	Street Orientation
Rectangular	0.1- 0.2- 0.4- 0.6- 0.8- 1- 1.2	0.25- 0.5- 1- 2- 4	0.4- 0.7- 1	E-W and N-S

Table 2: Parameter combinations investigated in the study

	(L1 / L2)= 0.1	(L1 / L2)= 0.4	(L1 / L2)= 0.8	(L1 / L2)= 1.2
(H/W)= 0.25				
(H/W)= 0. 5				
(H/W)= 1				
(H/W)= 2				
(H/W)= 4				

Results

Effect of Spacing Ratio (L1/L2)

The results indicate that the cooling loads for the simulated shapes are increased by about 20.7% with increasing the spacing ratio (L_1/L_2) from 0.1 to 1.2 for the square shape with width to length ratio equals to 1 and aspect ratio equals to 0.25 at the East- West orientation (E-W) in ECOTECT (which means increasing the distance between buildings from 2.2 m to 26.8 m in this case) as shown in (fig. 2). Increasing the aspect ratio (H/W) has a slight impact on affecting the percentage of increasing of the cooling loads. Increasing the spacing ratio from 0.1 to 1.2 increased the cooling loads by about 20.7% and 21.7% in the case of aspect ratio equals to 0.25 and 4 respectively.

Increasing the spacing ratio from 0.1 to 1.2 increased the cooling loads by about 14.9% and 15.7% in the case of aspect ratio equals to 0.25 and 4 respectively. This percentage of increasing is decreased to reach 7.2% and 9% with changing the street orientation from the (E-W) to the (N-S) in ECOTECT as shown in (fig. 2). Increasing the spacing ratio decreased the potential of adjacent shading and increased the solar radiation on building's façades. This explains the bad effect of increasing the spacing ratio in the summer periods.

The same trend can be observed in the results of IES program, which indicates high validity of the outcomes.

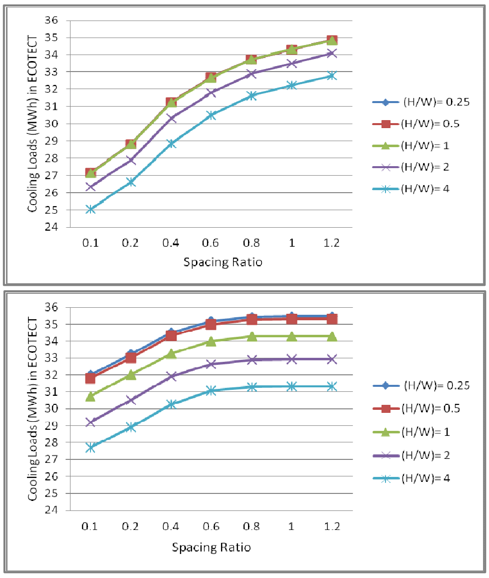


Fig. 2. (A): Cooling loads in the (E-W) street by ECOTECT, (B): Cooling loads in the (N-S) street by ECOTECT

Increasing the spacing ratio in the case of the East- West street increases the solar radiation on the east and west façades. However, in the case of the North- South street, the spacing ratio affects the north and south façades. Taking into consideration the low latitude position of the sun in the morning and evening of the summer periods which increases the solar potential on the east and west façades comparing with the south one. This explains the large increasing in the cooling loads with increasing the spacing ratio in the case of the East-West street comparing with the North- South one. It is noticed that the percentage of increasing in the cooling loads is decreased by decreasing the width to length ratio. As shown in (fig. 3), the percentage of increasing in the cooling loads is decreased from 20.8% to 16.3% and 10.5% with decreasing the width to length ratio (D/L_2) from 1 to 0.7 and 0.4 respectively. With increasing the width to length ratio, the surface area of the east and west façades increased. This explains the increasing in the cooling loads with increasing the width to length ratio. So it is recommended to pay more attention to the spacing ratio as the building be closer to the square shape and on the East- West street orientation.

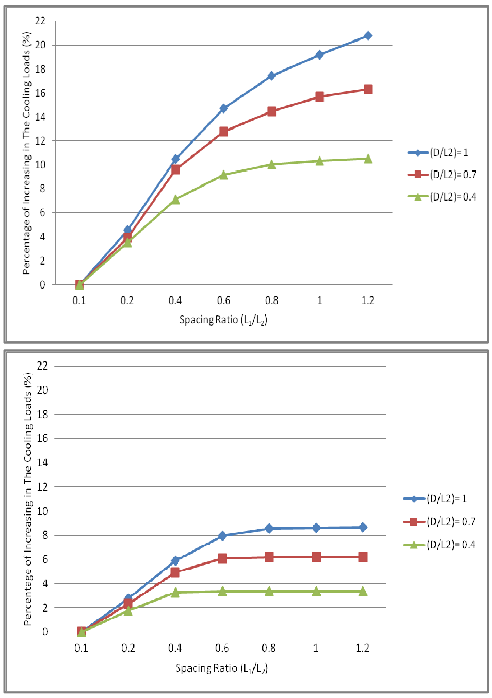


Fig. 3. a: The percentage of increasing in the cooling loads in the (E-W) street, b: in the (N-S) street

Although the spacing ratio has a large effect on the cooling loads, it has a slight effect on the heating loads. As shown in (fig. 4), increasing the spacing ratio (L_1/L_2) from 0.1 to 1.2 for the square shape at the East- West orientation (E-W) in ECOTECT reduced the heating loads by about 3.6% and 2.7% in the case of aspect ratio equals to 4 and 0.25. The same trend can be shown in IES with the percentage of decreasing reaches to about 2.2% and 3.5% in the case of aspect ratio equals to 0.25 and 4 respectively as shown in (fig. 4). Increasing the spacing ratio increases the solar potential on building's façades which decreases the heating loads. Changing the street orientation from the (E-W) to the (N-S) have a slight impact in affecting the percentage of decreasing in the heating loads.

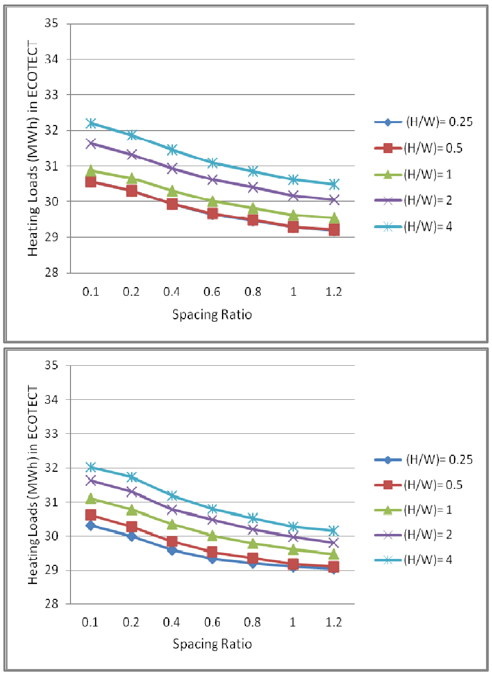


Fig. 4. a: Heating loads in the (E-W) street by ECOTECT, b: Heating loads in the (N-S) street by ECOTECT

The total loads take the same trend of the cooling loads. Increasing the spacing ratio (L_1/L_2) from 0.1 to 1.2 for the square shape at the East-West orientation (E-W) in ECOTECT increased the total loads by about 11% and 10.5% in the case of aspect ratio equals to 0.25 and 4 respectively. A similar percentage of increasing can be observed on

IES which reach to about 6.8% and 5.9% in the case of aspect ratio equals to 0.25 and 4 respectively as shown in (fig. 5). So it is recommended to use a smaller spacing ratio in the East- West streets in order to reduce the energy consumption. A spacing ratio equals to 0.1 is considered the optimum case for the cooling and total energy requirements.

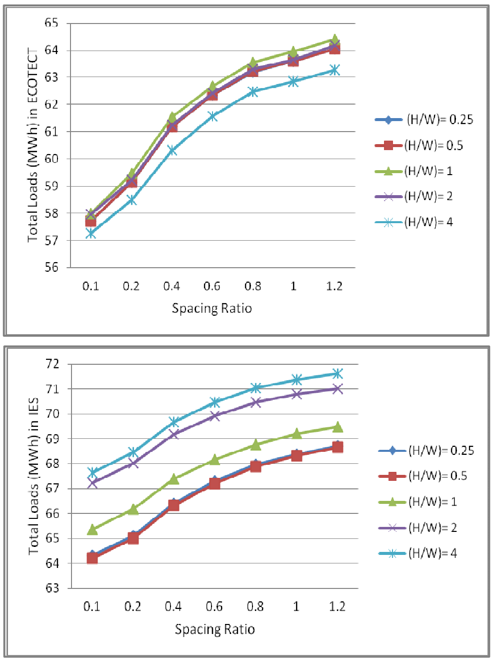


Fig. 5. a: Total loads in the (E-W) street by ECOTECT, b: by IES

It can be noticed that changing the street orientation from the (E-W) to the (N-S) in ECOTECT decreased the percentage of increasing in the total loads to reach 3.5% and 2.9% in the case of aspect ratio equals to 0.25 and 4 respectively. However, increasing the spacing ratio in IES reduces the total loads by about 2.4% and 2.7% in the case of aspect ratio equals to 0.25 and 4 respectively as shown in (fig. 6). There is a flexibility to use any spacing ratio in the North- South streets as the difference in the energy consumption doesn't exceed 4%. However, taking the heating requirements into consideration, it is recommended to use a large spacing ratio in the North- South streets in order to increase the solar radiation on the south façades which reduces the heating loads and slightly increases the cooling loads. This is due to the high angle of the sun in the midday when it is opposite the south façades. The discrepancy in results between ECOTECT and IES can be explained as a result of different load calculation techniques, calculation engines and discrepancy in materials and their associated thermal properties found in the programs. ECOTECT uses the worst case annual design load while the ASHRAE load calculator uses a worst month scenario (January) for heating loads and 5 months (May-September) for cooling loads (Kumar, 2008).

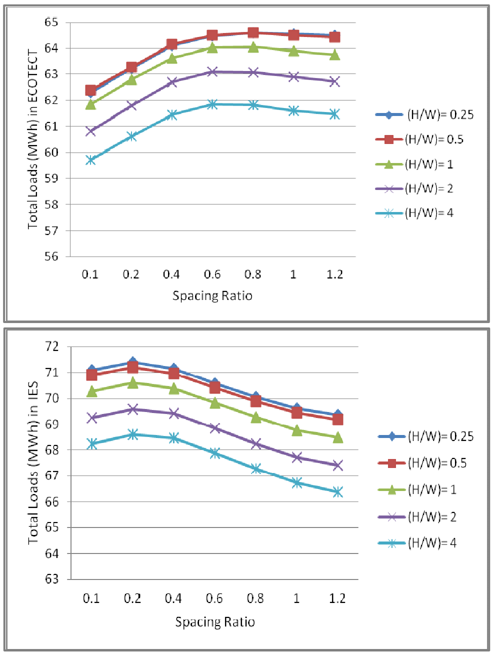


Fig. 6. a: Total loads in the (N-S) street by ECOTECT, b: by IES

Effect of Aspect Ratio (H/W)

The results indicate that the cooling loads for the simulated shapes are decreased by about 4.8% with increasing the aspect ratio (H/W) from 0.25 to 4 for the square shape with width ratio equals to 1 and spacing ratio equals to 0.1 at the East- West orientation (E-W) in ECOTECT (which means reducing the street's width from 80 m to 5 m) as shown in (fig. 7.a). The percentage of reduction reaches to about 2.7% for the same case in IES. Increasing the aspect ratio increases the shading potential and thus decreasing the solar radiation which reduces the cooling requirements.

It is noticed that the values of aspect ratio smaller than 1 have the same cooling loads. The percentage of reduction increased to reach 11.6% in the case of the North- South street in ECOTECT as shown in (fig. 7.b). It reaches to 8.4% in IES. The reduction in cooling loads can be explained as the increasing of aspect ratio in the simulated models reduced the solar radiation on the south façade in the case of the East- West street orientation; it reduced the solar radiation on the east façade in the case of the North- South street orientation. As mentioned previously, the east façade is more critical in determining the cooling loads in the summer periods than the south one due to the low angle of the sun in the morning comparing with the high angle of it in the midday.

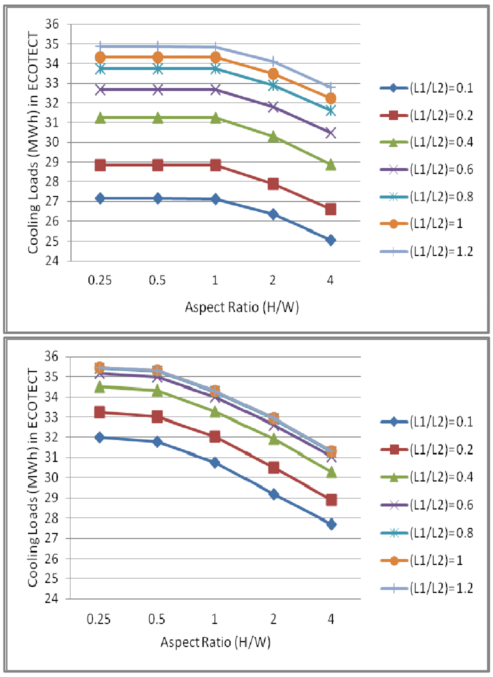


Fig. 7. a: Cooling loads in the (E-W) street by ECOTECT, b: Cooling loads in the (N-S) street by ECOTECT

As a result, increasing the surface of the façade overlooking the street and increasing its percentage to the total exposed surface can increase the role of the aspect ratio in affecting the cooling loads. This means that increasing the building elongation by decreasing the width to length ratio (D/L_2) increases the impact of the aspect ratio. As shown in (fig. 8), decreasing the aspect ratio from 4 to 0.25 in the case of the East- West street orientation and with spacing ratio equals to 0.1 increases the cooling loads by about 5%, 5.3% and 8.6% in the case of building geometry with width ratio equals to 1, 0.7 and 0.4 respectively. Changing the street orientation 90^{o} to the North- South for the same geometries increases these percentages to reach 13.1%, 14.4% and 18.2% respectively.

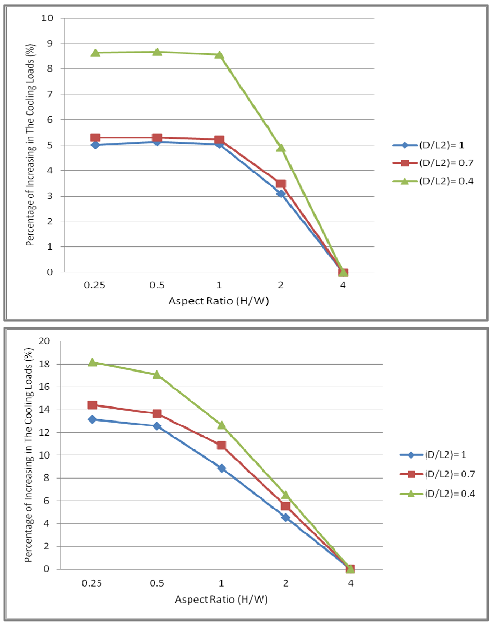


Fig. 8. a: The percentage of increasing in the cooling loads in the (E-W) street, b: by the (N-S) street

Increasing the aspect ratio from 0.25 to 4 for the square shape at the (E-W)orientation in ECOTECT increases the heating loads by about 3.6% and 2.6% for the case of spacing ratio equals to 0.1 and 1.2 respectively as shown in (fig. 9.a). The percentage of reduction reaches to about 13.9% and 12.4% in IES for the case of spacing ratio equals to 0.1 and 1.2 respectively. So a larger aspect ratio is advisable for reducing the heating loads in the East-West due to the increasing in the solar potential on the south façades. Changing the street orientation to the (N-S) decreases the percentages of increasing to reach 2.5% and 1.4% respectively as shown in (fig. 9.b). Decreasing the width ratio has an effect in increasing these percentages to reach 4.7% and 3% in the case of width ratio equals to 0.4. So it is concluded that increasing the aspect ratio slightly decreased the cooling loads and greatly increases the heating loads in the East- West streets. In contrast, it largely decreases the cooling loads and slightly increases the heating loads in the North- South streets.

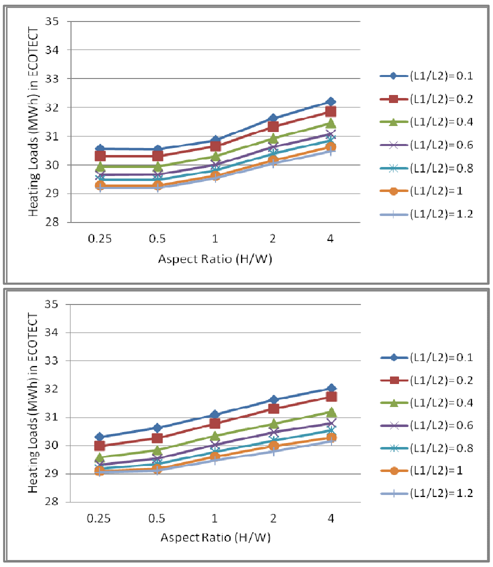


Fig. 9. a: Heating loads in the (E-W) street by ECOTECT, b: Heating loads in the (N-S) street by ECOTECT

From the total loads point of view, increasing the aspect ratio at the East- West street orientation has less than 1% of reduction in the total loads in ECOTECT, however it increases the total loads by about 5.1% in IES as shown in (fig. 10).

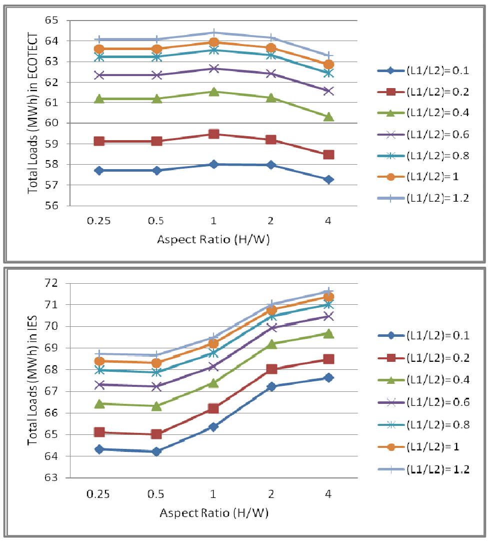


Fig.10. a: Total loads in the (E-W) street by ECOTECT, b: by IES

Showing (fig. 11), it is evident that the effect of aspect ratio in affecting the total loads differs according to the street orientation. Increasing the aspect ratio at the North- South street orientation decreases the total loads by about 4.2% and 4% in ECOTECT and IES respectively.

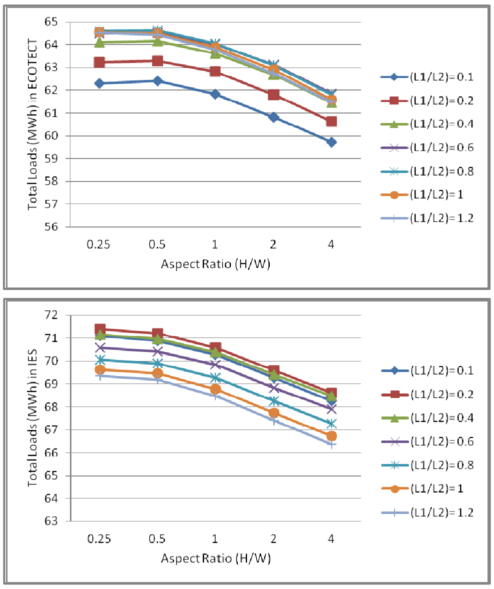


Fig. 11. a: Total loads in the (N-S) street by ECOTECT, b: by IES

(Fig. 12) presents the more preferable option in the (E-W) street in order to be applied in the Gaza Strip. The model has a spacing ratio (L1/L2) equals 0.1 and aspect ratio (H/W) equals 0. 5. The more preferable option in the (N-S) street has a spacing ratio (L1/L2) equals 1.2, and aspect ratio (H/W) equals 4.

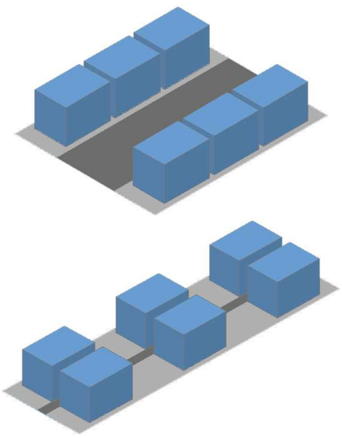


Fig. 12. a: The more preferable option in the (E-W) street, b: in the (N-S) street

Effect of Street Orientation

The study compares the thermal performance of the two main street orientations which are the east-west and the north-south orientations. The study takes into consideration the three width to length ratio of buildings which are 0.4, 0.7 and l and two spacing ratio (L1/L2) which are 0.1 and 1.2 and two aspect ratio (H/W) which are 0.25 and 4 in order to investigate the impact of these variables in affecting the role of street orientation, see (fig. 13).

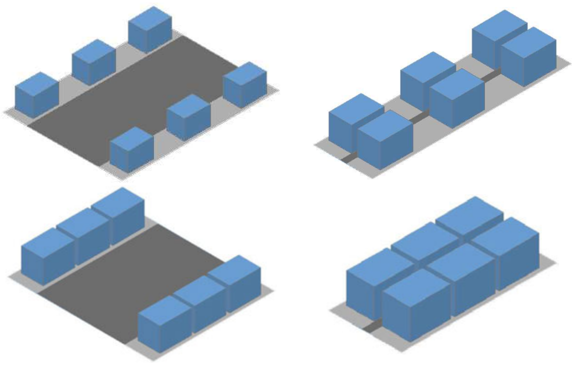


Fig. 13. a: The simulated cases in the study

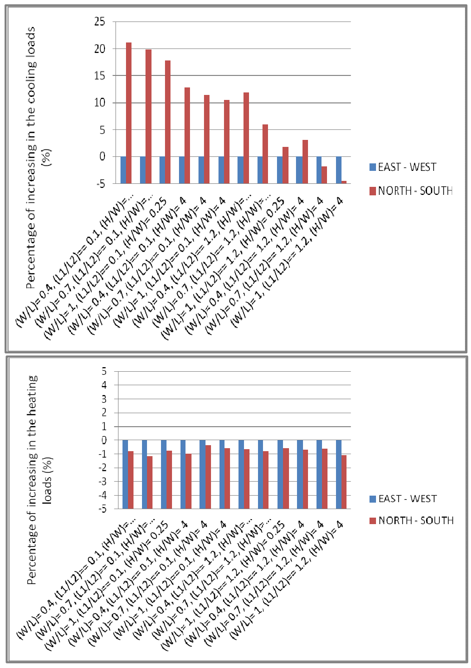


Fig. 14. a: The percentage of increasing in the cooling loads by ECOTECT, b: The percentage of increasing in the heating loads by ECOTECT

As shown in (fig. 14), the street orientation has a great effect on the cooling loads especially in small values of aspect ratio. For more details, changing the street orientation from the east- west to the north-south orientation with (H/W) equals to 0.25 can increase the cooling loads by about 21.1%, 19.9% and 17.8% in the case of buildings with width ratio equals to 0.4, 0.7 and 1 respectively and with small spacing ratio 0.1 by ECOTECT.

Increasing the aspect ratio can reduced the difference to reach 12.9%, 11.5% and 10.5% respectively. Hence, it can be possible to minimize the bad impact of the north- south streets by increasing the aspect ratio which means increasing the buildings height so that a large shaded area of the east and west façades can be achieved. The street orientation has a slight effect on the heating loads. The north- south orientation has a better thermal response in the winter periods of about 2.2%, 1.5% and 1.6% in the case of buildings with width ratio equals to 0.4, 0.7 and 1 respectively and with large aspect ratio in ECOTECT as shown in (fig. 14).

From the total loads point of view, it can be observed from (fig. 15) that the east- west street is the more preferable one in both ECOTECT and IES for all the simulated cases especially in the case of large aspect ratio (H/W) equals to 4 and large spacing ratio (L1/L2) equals to 1.2. For more details, changing the street orientation from the east- west to the north-south orientation with a small (H/W) equals to 0.25 and a small spacing ratio (0.1) increases the total loads in ECOTECT by about 10.2%, 9% and 8% in the case of buildings with width ratio equals to 0.4, 0.7 and 1 respectively. It increases the total loads in IES by about 14.7%, 12.2% and 10.5% in the case of buildings with width ratio equals to 0.4, 0.7 and 1 respectively. However, changing the street orientation from the east- west to the north- south orientation with a large (H/W) equals to 4 and a large spacing ratio equals to 1.2 decreases the total loads in ECOTECT by about 1.2% and 2.8% in the case of buildings with width ratio equals to 0.7 and 1 respectively. It decreases the total loads in IES by about 3.5%, 5.9% and 7.3% in the case of buildings with width ratio equals to 0.4, 0.7 and 1 respectively. Table 3 illustrates the 12 cases simulated in the study and the preferable street's orientation in each case.

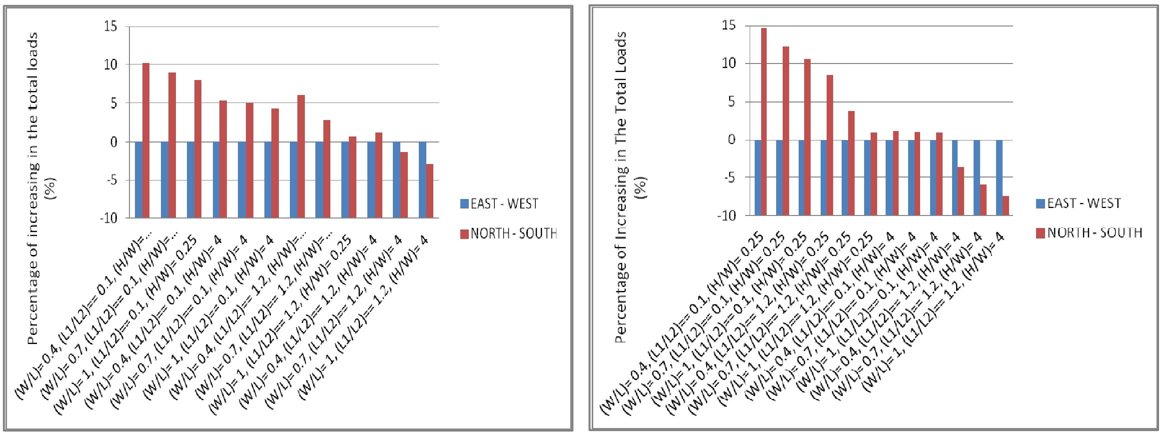
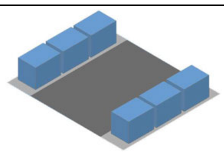
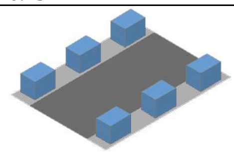
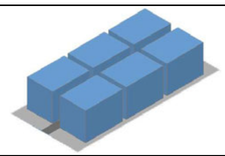
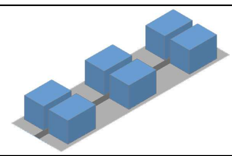


Fig. 15. a: The percentage of increasing in the total loads by ECOTECT, b: by IES

Table 3: The 12 options investigated in the study

	(L1/L2)= 0.1, (H/W)= 0.25	(L1/L2)= 1.2, (H/W)= 0.25	(L1/L2)= 0.1, (H/W)= 4	(L1/L2)= 1.2, (H/W)= 4
Perspective				
Width ratio= 0.4	(E-W) street is better than (N-S) street by about 14.7% in the total loads	(E-W) street is better than (N-S) street by about 8.5% in the total loads	(E-W) street is better than (N-S) street by about 1.1% in the total loads	(N-S) street is better than (E-W) street by about 3.5% in the total loads
Width ratio= 0.7	(E-W) street is better than (N-S) street by about 12.2% in the total loads	(E-W) street is better than (N-S) street by about 3.8% in the total loads	(E-W) street is better than (N-S) street by about 1% in the total loads	(N-S) street is better than (E-W) street by about 5.9% in the total loads
Width ratio= 1	(E-W) street is better than (N-S) street by about 10.5% in the total loads	(E-W) street is better than (N-S) street by about 0.95 % in the total loads	(E-W) street is better than (N-S) street by about 0.9% in the total loads	(N-S) street is better than (E-W) street by about 7.3% in the total loads

Incident Solar Radiation

It's evident that the incident solar radiation is the main responsible factor in the thermal response of the simulated cases. As the simulated cases is taken to be the middle building in the urban configuration, which surrounded from each the south, west and east facade, the incident solar radiation on these façades have to be analyzed. About 24 cases was handled which included three width ratios (1, 0.7, 0.4), two street orientations (E-W, N-S), two aspect ratios (H/W) (0.25, 4) and two spacing ratio (SR) (0.1, 1.2). as indicated in (fig. 16), the building in an urban configuration of aspect ratio equals to 4 and spacing ratio equals to 0.1 with an E-W street orientation receives the least amounts of incident solar radiation. This explains why this model achieves the best thermal behavior in summer period and the worst behavior in winter.

It's evident that decreasing the spacing ratio (SR) from 1.2 to 0.1 for the same (H/W) ratio equals to 4 reduces the incident solar radiation on the south, west and east facades by about 15%, 59% and 71.6% respectively. This demonstrates the significant role of mutual shading from the adjacent building in affecting the incident solar radiation on building façades and thus its thermal performance. To indicate the effect of aspect ratio in affecting the role of spacing ratio, the incident solar radiation in the case of (H/W) ratio equals to 0.25 was analyzed. Decreasing the spacing ratio (SR) from 1.2 to 0.1 for

(H/W) ratio equals to 0.25 reduces the incident solar radiation on the west and east façades by about 56% and 68.7% respectively. It's obviously that increasing the (H/W) ratio has a slightly effect in decreasing the impact of the spacing ratio in reducing the solar radiation on the west and east façades. On the other hand, increasing the (H/W) ratio greatly affects the solar radiation on the south façade. As shown in the figure, the solar radiation on the south façade is the same in the case of (SR) equals to 0.1 and 1.2 for (H/W) ratio equals to 0.25 and that's mean that there is no adjacent shading on the south façade.

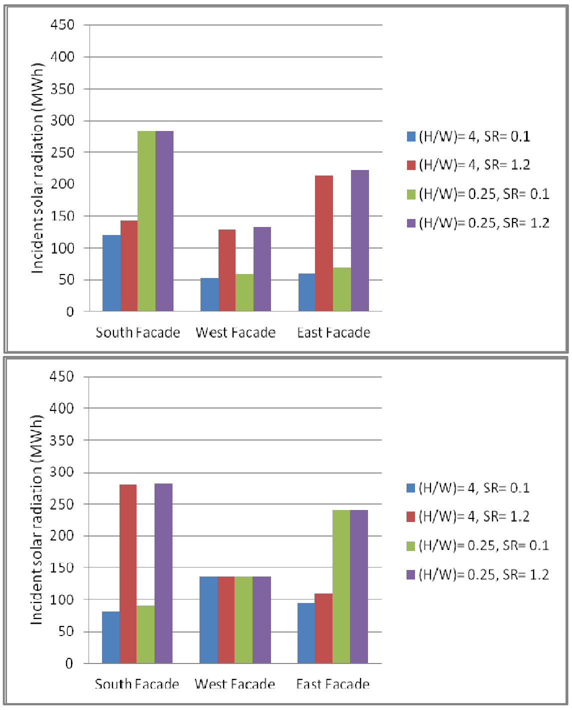


Fig. 16. a: Solar radiation in the (E-W) Street, b: in the (N-S) Street

In terms of aspect ratio, it is evident from figure (16) that its effect is more noticeable on the south façade. Increasing the aspect ratio (H/W) from 0.25 to 4 in the case of spacing ratio equals to 0.1 has an effect in decreasing the incident solar radiation on the south, west and east façades by about 57.2%, 9% and 12.6% respectively. By increasing the spacing ratio to 1.2, the percentage of reduction in the solar radiation reduced to 49.7%, 2.5% and 3.6% on the south, west and east façades respectively.

Conclusion

Buildings proportions have a joint relation with the urban canopy such as the street width and the spacing between buildings. The relation between the architectural proportions of the individual building and the urban parameters can affects the solar potential on the buildings surfaces and the mutual shading from the adjacent buildings. Building length has to be determined to provide a small spacing ratio (L_1/L_2). Also, building height have to be determined to provide a large aspect ratio (H/W) especially in the north- south street. Increasing the aspect ratio slightly decreased the cooling loads and greatly increases the heating loads in the East- West streets. In contrast, it largely decreases the cooling loads and slightly increases the heating loads in the North- South streets. Also, increasing the aspect ratio in the north- south streets can enhance the thermal performance of their building and reduce the difference between them and the optimum orientation of the street. Increasing the spacing ratio (L1/L2) from 0.1 to 1.2 for the square shape at the (E-W) street orientation increases the cooling loads by about 20.7%. Changing the street orientation from the (E-W) to the (N-S) orientation with small values of aspect ratio (H/W) equals to 0.25 can increase the cooling loads by about 21.1%.

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Appendix 1

Table 1: Default settings for ECOTECT and IES

	ECOTECT	**IES**
Thermal Condition		
HVAC System	Full Air Conditioning	Full Air Conditioning
Thermostat Range	18.0^{0}C- 26.0^{0}C	18.0^{0}C- 26.0^{0}C
Use of the building/ Hours of Operation	On continuously	On continuously
Model settings		
Solar reflected fraction	-	0.05
Furniture mass factor	-	1.00
Design condition		
Clothing (clo)	1.0	-
Humidity	60.0	-
Air speed	0.5 m/s	-
Lighting level	300 lux	300 lux
Occupancy	0	0
Internal heat gain		
Sensible gain	0	0
Latent gain	0	0
Infiltration rate		
Air change rate	0	0
Wind Sensitivity	0	0
Construction		
Exterior walls		
U-value	1.77	1.9487
Roof		
U-value	0.896	0.9165
Ground-contact/exposed		
U-value	0.88	0.7059
Window		
U-value	6.0	5.5617

أثر الاشكال والفراغات التخطيطية على الاداء الحراري في مناخ البحر المتوسط لقطاع غزة

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الكلمات المفتاحية: الهندسة الحضارية؛ معدل التباعد؛ معدل الارتفاع؛ أحمال التبريد والتدفئة.

ملخص البحث. تدرس الورقة البحثية الأداء الحراري للأشكال الهندسية المختلفة للوحدات السكنية الواقعة في مناخ البحر الأبيض المتوسط لقطاع غزة وضمن تكوينات حضرية مختلفة، ويعتمد البحث على استخدام برامج الكمبيوتر ECOTECT و IES، وقد أظهرت النتائج تأثيراً حرارياً كبيراً للشكل الحضري. هذا وقد خرجت الورقة البحثية بنتيجة مفادها أن نسبة المسافات بين المباني إلى الطول الأمامي للوحدة السكنية والمساوية ٠,١ ونسبة ارتفاع المبنى إلى عرض الشارع والمساوية ٠,٥ هي الخيار الأفضل حرارياً في الشوارع الشرقية- الغربية بقطاع غزة، فيما يتضمن الخيار الأفضل حرارياً في الشوارع الشمالية- الجنوبية نسب المسافات بين المباني إلى الطول الأمامي للوحدة السكنية والمساوية ١,٢ ونسبة ارتفاع المبنى إلى عرض الشارع والمساوية ٤,٠. ومن هنا فإنه من الضروري تحديد النسب والأبعاد المتعلقة بالمباني في ظل فهم كامل للعلاقة بينها وبين النسيج الحضري، كذلك توصي الورقة باستغلال مزايا التكوينات العمرانية المتبادلة رأسياً في تحقيق التظليل على أسقف وواجهات المباني وذلك من خلال استخدام ارتفاعات مختلفة للمباني.