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Technical note

The effect of urban layout, street geometry and orientation on shading conditions in urban canyons in the Mediterranean

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ABSTRACT

The paper presents the results of shading analysis which was carried out as part of a wider comparative analysis of two sites with different characteristics in terms of street geometry and urban density. The first experiment site was a traditional settlement in the island of Tinos, Greece, and the second was a relatively newly built part of the capital city of the island. Also a parametric shading analysis was carried out in order to examine a number of parameters that influence shading conditions in urban canyons.

The paper aims in analyzing the effect of parameters such as urban layout, street geometry and orientation on solar access and shading conditions, which strongly affect urban canyon microclimate. The results of shading simulations are compared to the results of experimental measurements of air and surface temperatures and to parametric thermal analysis results. The conclusions can contribute in the formulation of urban design guidelines.

1. Introduction

Urban canyon microclimate is largely affected by solar access and shading conditions, since solar access affects air and surface temperatures. Canyon geometry and parameters such as street pattern, height of buildings/street width ratio and street orientation determine solar access and shading conditions. Consequently, they play a crucial role in thermal comfort in open spaces and affect largely the energy performance of buildings. It has also been suggested that urban geometry is much more important at the microscale than the thermal behavior of materials and the albedo effect [1]. Additionally, it is of high importance the question whether the investigation of urban microclimate can lead to the formulation of specific urban design guidelines.

Solar access issues in relation to orientation, height/width ratio and latitude have been examined in the past [2]. Oke has investigated the way by which urban climate and street geometry are related and has also suggested optimum h/w ratios for mid-latitude cities [3]. The effect of urban geometry and orientation on solar access and shading conditions for different latitude conditions has been studied by researchers [4–7] while other studies have examined the relationship between urban density, orientation and solar access issues, in an effort to investigate urban design options [8–11].

In the past few years the microclimatic conditions in traditional settlements have been the subject of a number of studies, mostly in hot and arid climates [12–14]. The compact morphology and high h/w ratios, which characterize the traditional settlements in the Cycladic islands in Greece, respond in a most positive way to the local climate and thus the investigation of microclimatic conditions in such settlements can be of high interest.

2. Shading conditions in the experimental sites

2.1. Site selection

The sites examined are a traditional settlement in the island of Tinos, Greece, and a contemporary part of the capital city of the island (Fig. 1). The latitude of the area is 37° N. The traditional settlement is located on a SE–facing slope (Fig. 2) and is characterized by compact design, high h/w ratio, undulate street pattern and covered parts of streets. The h/w ratio of the streets is between 4 and 2. The contemporary site is located on flat terrain and is characterized by straight streets and lower H/W ratio (0.9 and 0.7). The axes of the streets have the same orientation in both sites. The local climate is characterized by high solar intensity and strong northern winds (Fig. 3). Therefore, adequate shading is of high importance for the summer period. In winter however, solar access is desirable.

2.2. Shading simulations

In order to examine the effect of different parameters on microclimate in urban canyons, a shading analysis was carried out

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Fig. 1. The contemporary (a) and the traditional (b) site.

using the Autodesk Ecotect Analysis tool. The program was selected over other simulation programs because of its high capability to be successfully used for the performance of shading and solar access analysis in urban planning. It is noted that the program was not used for the performance of thermal analysis of buildings. The program user creates a 3D model of the area examined and then the tool can calculate and visualize shading conditions of the entire model as well as perform detailed shading and solar access analysis on any selected surfaces. Also, incident solar radiation on surfaces can be calculated over any period as long as the area's weather file is used as input. The simulations were performed for June and December.

Fig. 4 presents shadow range of the two sites on June 21st and December 21st. Two E-W canyons, one in the contemporary (street 1) and one in the traditional site (street 2), were selected for more detailed analysis and comparison. The street in the traditional settlement has a h/w ratio of 2, while the h/w ratio in the contemporary site is 0.7. Figs. 5 and 6 present incident solar radiation and shading conditions in two E-W streets on June 21st, while Figs. 7 and 8 present the corresponding stereographic diagrams of the above streets. Table 1 presents average shading percentages and incident solar radiation for the horizontal surfaces and southern facades in the above two streets.

Total sunlight hours of the street surfaces in the traditional site are presented in Fig. 9 for June 21st and December 21st. Fig. 10 presents total sunlight hours of the street surfaces in the contemporary site for June 21st and December 21st.

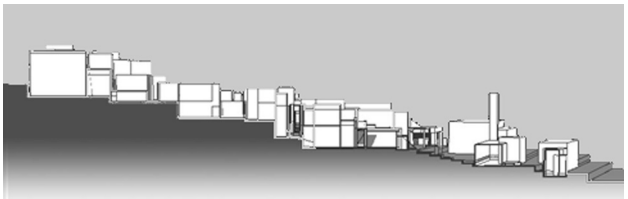

Fig. 2. Section of the traditional settlement.

The comparison between the two E-W canyons demonstrates that shading percentages in the traditional site are three times higher to those in the contemporary site during summer months (Table 1), reaching 88% in August. Numerical data on incident solar radiation demonstrates a similar ratio between the two sites. Shading percentages of southern facades in the traditional site are double compared to those in the contemporary site during summer months.

The compact layout of the traditional settlement, the high h/w ratios, the presence of covered streets and the absence of large open spaces contribute to limited solar access at pedestrian level. Building morphology characterized by volumes insetting, extruding and intersecting each other, contributes to additional shading of surfaces. In wintertime, the orientation of the settlement, the location on a south-east sloping terrain and the escalating building morphology contribute to favorable conditions for the buildings' main facades in terms of solar access.

In wintertime, solar access conditions on buildings with southern orientation in the contemporary site are around 30%, which is satisfactory. The height/width ratio of the street (0.7) ensures adequate insolation of the building facades on this side of the street (Table 1). The corresponding shading percentages of southern facades in the traditional site are almost three times higher at pedestrian level compared to the contemporary site, reaching 85%, This problem is partly solved by the buildings' layout with primary uses and courtyards on upper levels facing south, which contributes in maximizing solar gains and minimizing northern wind exposure in winter. Traditionally, lower levels of buildings were used for auxiliary uses.

Finally, the horizontal surface of the streets on N–S axis has better solar access than the street on the E–W axis in wintertime.

3. Parametric shading analysis

3.1. Method

A shading/solar access analysis was performed as a number of case models were created in which certain parameters and their