Schematic design proposals of the implementation of PDEC in the urban open spaces of Athens

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ABSTRACT

This paper summarises a series of design proposals, which aim at exploring in an architectural way, the implementation of PDEC in the urban spaces of Athens. These design proposals refer to the larger scale of the typical urban block, as well as the intermediate scale of the urban square, and attempt to increase convective and evaporative cooling within the dense city fabric. For a city with a hot and relatively dry climate, like Athens, the effect of enhanced air circulation at pedestrian level can significantly improve thermal conditions during the summer.

1. DIFFERENT ASPECTS OF THE CLIMATE OF ATHENS

1.1 Summer Climatic Conditions

The warm period in Athens is not usually confined to the summer, but extends to the months May and September. The basic climatic data for this period are presented in Table 1. It should be noted, though, that mean air temperatures are significantly lower and are not representative of the temperatures, which prevail in urban open spaces during noon and afternoon hours.

Climatic data from the N.T.U.A. meteorological station for the period 1994-1999 (http://www.chi.civil.ntua.gr) show that in Athens, maximum temperatures (25-40 degrees C, with a mean value of 30 degrees C) coincide with minimum relative humidity values (20-40%, with a mean value of 30-35%) around the afternoon.

Therefore, it is clear that in Athens, during summer afternoons, thermal comfort conditions in urban open spaces are way beyond thermal comfort. Furthermore, it can be deduced that shading, combined with ventilation and evaporative cooling are the most efficient ways to improve microclimatic conditions and reduce thermal discomfort.

1.2 The Urban Heat Island

Central Athens has a mesoclimate, which is formed by the equal distance from the sea and the mountains, and especially by the increased density of the urban fabric. During the summer, the microclimate in the central districts of the city is strongly influenced by the Athens urban heat island, which is described and has been largely studied and documented by Santamouris in (Santamouris et al., 2000; Santamouris, 2001).

The causes of the Athens urban heat island phenomenon are consistent with the factors, which define it in every other city of the world (Oke, 1995; Landsberg, 1981). The intensity of the phenomenon (i.e. the difference between air temperature in the central districts and the suburban and rural areas) can reach up to 14 degrees C, with a mean increase of 10 degrees C (Santamouris et al., 2000). As a result, the already high dry-bulb summer temperatures are further elevated, thus contributing to the further

Table 1: Basic climatic data for Athens for the period May-September, adapted from (Pelekanos, 1991).

	May	Jun	Jul	Aug	Sep
Mean Max T (C)	25.0	29.8	32.5	32.6	28.6
RH (%)	59	51	47	48	55
Sol. rad (kWh/m^2)	190	204	219	202	149
Sunshine (hrs/m)	303	335	373	357	277
Wind Direction	SW	S	N	N	N
Wind Speed (m/s)	2.3	2.7	3.4	3.3	2.7

degradation of the microclimatic and thermal quality of urban open spaces.

1.3 The urban canyon effect

The urban canyon is described by its geometric characteristics, which are combined in the ratio of the building height to the width of the street (H/W). In the streets of Athens, the H/W ratio, which is specified by the Greek General Building Code, is equal to 1.5. In reality, most of the central districts were built prior to this legislation, and as a result, H/W ratios may well exceed this figure (Fig. 1). According to Oke, for this ratio, and for an airflow perpendicular to the long axis of the urban canyon, the air passes over the roofs of the buildings, never entering the street (Oke, 1995).

As a result, many streets of Athens have very poor ventilation conditions when the direction of the prevailing winds is perpendicular to their longitudinal axis. This fact is denoted by measurements carried out by Santamouris in a street in central Athens, which show that air velocities are lower than 0.5 m/s inside the street, while they exceed 4 m/s at the flat roofs level (Santamouris et al., 2000).

The consequences of the morphology of the urban canyons and thus of the urban fabric on the air movement is very important for the conditions, which prevail inside the urban streets. The sufficient ventilation of a street during the summer removes the heated air and improves thermal comfort conditions at the circulation level of the pedestrians. Furthermore, throughout the year, the sufficient air circulation inside the urban streets results in the dispersion of air pollutants and exhaust fumes from the street.

Figure 1: Views of typical streets in Athens.

2. PRESENTATION OF THE PROPOSALS

2.1 Introduction

The schematic design proposals, which will be presented, attempt to architecturally integrate passive down draught evaporative cooling towers (referred to, from now on, as PDEC towers) in specific points of the city. PDEC towers create a downward air movement, where the air captured at the upper end passes through water "filters", which may be micronisers, wetted cellulose pads (Givoni, 1998) or ceramic bricks (Papagiannopoulos and Ford, 2003) in order to be cooled through the process of evaporation. The evaporation of water causes a significant reduction of the ambient air temperature, which may reach 10 to 15 degrees C (http://www.bgu.ac.il/CDAUP/energy.html).

The two projects focus on different aspects of the open space of the city: the narrow urban street, which is perpendicular to the direction of the prevailing winds during the summer, the open space inside the urban blocks, and the urban square, which is almost completely deprived of vegetation and water elements. Their design was graphically explored through the construction of three-dimensional models using the Form Z software.

Finally, it should be noted, that although these proposals concern the open space of the city, PDEC can also be implemented in existing multi-storeyed buildings, with the exploitation of existing elements, such as light-shafts.

2.2 The "Water Air VEgetation Celebration for the city of Athens" project

The present study proposes ways to increase air movement inside the urban fabric of Athens. In order to do this, the function of PDEC towers is combined with this of the solar chimneys. The main goal is to augment vertical air movement by creating a downward airflow at a given point of an urban block and a corresponding upward airflow at an adjacent point. The introduction of each element is determined not only by the orientation of the street and the direction of the prevailing winds, but also by the morphology of the buildings, the surface of open spaces and the use of streets and open spaces.

The main idea of this project was formulated by the authors in (Evangelinos et al., 2003), and was further developed by Bougiatioti & Oikonomou as an entry for the UIA "Celebration of Cities Competition".

2.2.1 Upward air movement. Introduction to the city geometry

The creation of an upward air movement in the city streets would help remove overheated air, air pollutants, and exhaust fumes from pedestrian level. For this reason, solar chimneys could be installed at the building facades.

The main facade of the typical multi-storeyed building is plain with continuous or separated linear balconies, which leave a 1-2 meters distance from the party wall (Fig. 2). It is precisely this space, which could accommodate solar chimneys and/or PDEC towers.

According to the orientation of the facade, the upper part of the solar chimney could differ in order to receive maximum solar energy. It is preferable, though, to situate solar chimneys at the southern facades of buildings because the increased solar exposure during summer could enhance their effectiveness.

2.2.2 Downward air movement. Introduction to the city geometry

Contrary to an upward airflow, a downward air movement should be created in open spaces, where air pollution levels are lower than in urban streets, in order to ensure that the airflow reaching the ground level is not only cooler, but also fresher and less polluted. In this project, PDEC towers were placed at the interior courtyards of the urban blocks, as well as on the facades of the buildings inside the urban streets. This was possible due to the overall redesign of the streets, into low-traffic, calming streets,

Figure 2: Spaces between the balconies of adjacent multi storeyed buildings in the centre of Athens.

which provide adequate space for pedestrian circulation, vegetation, parking spaces and public transportation.

The interior courtyards of the urban blocks, (*akalyptoi*), are in most cases neglected and always fragmented into individual, small properties. Nevertheless, they constitute vital open spaces -the only remaining open spaces- in the densely built Athens. They are secluded from the polluted urban streets and over-shadowed by the surrounding buildings, and as a result have relatively good microclimatic and environmental conditions. The installation of PDEC towers could significantly improve thermal comfort conditions, as it would enhance ventilation and natural cooling. In this project, this intervention was also combined with an overall upgrade of these open spaces with other proposals, such as the planting of deciduous trees for shading and cooling, the design of water pools, the replacement of hard paving (concrete and asphalt) by soft and water-permeable materials (soil, grass and blocks placed on sand or soil), and the creation of open-air creative spaces for the inhabitants and the users of the surrounding buildings.

PDEC towers could also be placed at the northern facades of multi-storeyed buildings in order to receive the less possible solar radiation, and in a way similar to what was suggested earlier in the paper for solar chimneys. The combination of PDEC towers and solar chimneys in the same street would then create a continuous airflow at pedestrian level. At the same time, overheated and relatively dry air would be constantly replaced with cooler and more humid air, significantly improving open-air thermal comfort conditions.

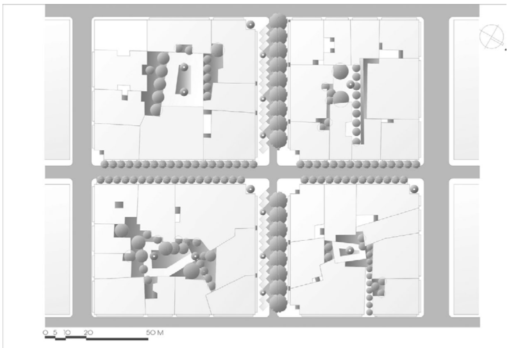

Figure 3: Plan of the study area.

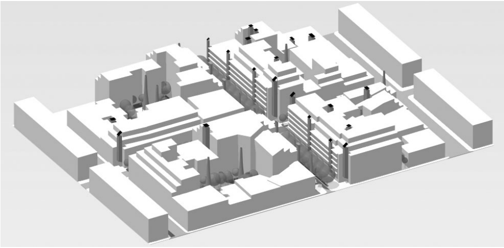

Figure 4: Perspective view of the study area. Rendering.

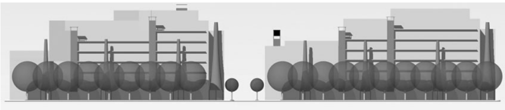

Figure 5: Longitudinal section of the street.

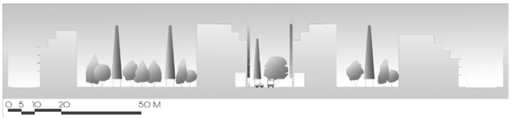

Figure 6: Section of the interior courtyards.

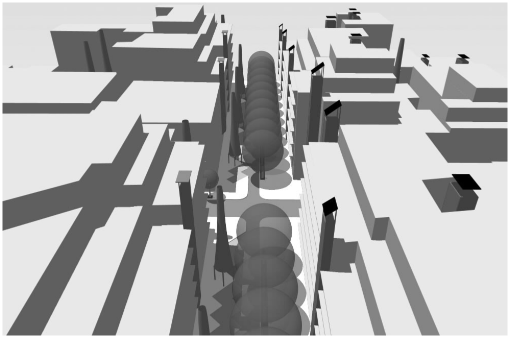

Figure 7: Perspective view of the street. Rendering.

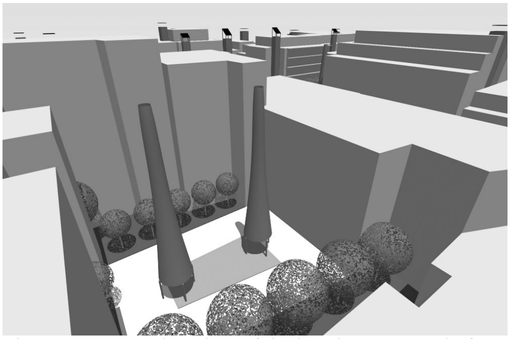

Figure 8: Perspective view of the interior courtyard of an urban block with PDEC towers. Rendering.

2.2.3 Schematic investigation

2.3 Shadum Evaporatis project

The present project was seen as a way of improving microclimatic conditions in urban squares of Athens, where neither shading devices nor vegetation exist for various reasons. The main reason is that some of these squares are situated above underground car parking lots and metro stations, with no provision for planting trees.

The project proposes an autonomous and eco-friendly tree, Shadum Evaporatis, which is primarily designed as an architectural landmark, strengthening the urban image of the squares. The main idea of this project was formulated by the authors in (Evangelinos et al., 2004).

A PDEC Tower

Shadum Evaporatis is primarily a PDEC tower, which provides the necessary evaporative cooling for the people congregating at its base. This function is incorporated in the "trunk" of the

Figure 9: Omonia Square and Kotzia Square in the centre of Athens situated over a metro station and an underground car parking, repsectively.

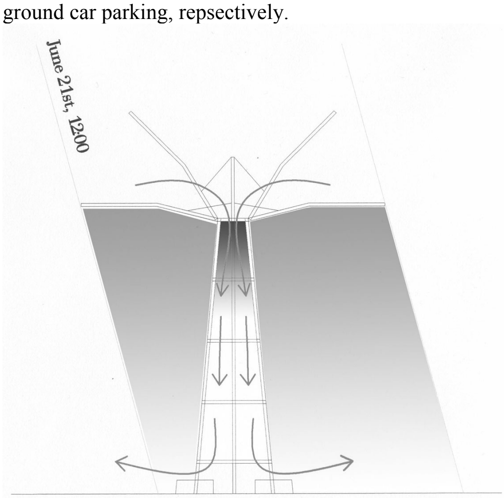

Figure 10: Diagram of the cooling and shading functions of Shadum Evaporatis.

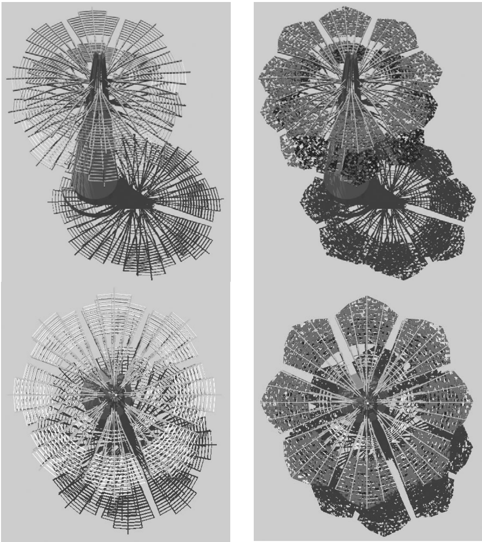

Figure 11: Plan and perspective view. Variations with wooden shades and deciduous plants.

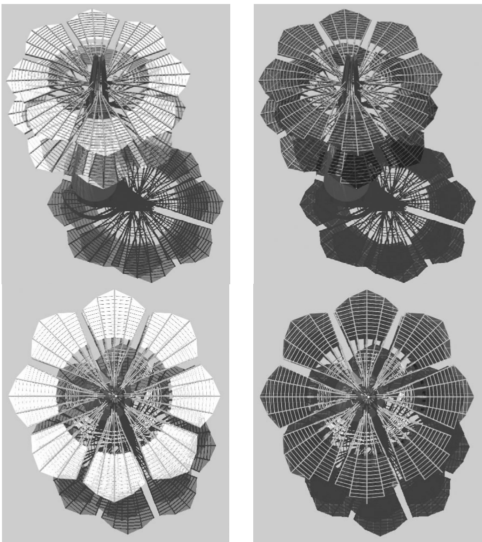

Figure 12: Plan and perspective view. Variations with PV cells and membranes.

tree. The cooled air exits from the lower part of the "trunk" at the circulation level.

The cooling effect of the PDEC tower is further enhanced by the shading effect, which is provided by the upper part ("foliage") of the tree. This consists of structural parts ("branches"), that support the elements -the "foliage"- which provide shading. These structural parts begin at the upper part of the tree and ex-

Figure 13: Schematic representation of Kotzia Square with Shadum Evaporatis structures used as city furniture.

tend to a certain length in order to provide efficient shading. The light structure, which supports the "foliage" of the tree, is either fixed, or capable of moving in different directions.

Finally, similar to every other tree, there are different "species" of Shadum Evaporatis. The different "species" are actually the design variations of the structure in order to fit into the different squares, and act distinctly in every case. The main variations of Shadum Evaporatis include the different "foliage", which the "tree" can have. This "foliage" can be made of membranes, lightweight wooden shades in various sizes, PV cells, or deciduous climbing plants. The different "foliages" provide different shading effects, make the structure look more or less natural, and affect the structure's dependence on the city infrastructure.

3. CONCLUSIONS

Many central streets and squares in Athens are deprived of vegetation, which can provide shading and cooling, during the overheated period. The water surfaces, which are usually integrated in the centres of the urban squares, are far too isolated to provide sufficient cooling, in the summer. Finally, city surfaces are constructed of artificial, dark coloured, heavy-weight materials, which during the day absorb large sums of solar radiation and radiate heat, significantly raising the mean radiant temperature. All the above drastically reduce the use of urban open spaces in Athens during summer days. People quickly cross these spaces, and search for more shaded and fresh areas to sit and relax.

In this paper, the use of PDEC towers in various open spaces of central Athens was seen as a way, which can help improve the microclimate and reduce thermal discomfort, through the effect of evaporative cooling and enhanced air circulation.

It is obvious that the efficiency of the aforementioned proposals can only be fully understood and justified through thorough CFD testing. The main objective of this paper was to take the first step towards this direction and schematically explore the possibilities of inserting PDEC towers in the urban fabric of Athens.

From an architectural point of view, it could be assumed that PDEC towers could help reinforce the image of certain streets in the centre of Athens. This could be achieved through the appropriate use of colour, and through repetition/creation of visual sequences. In urban squares, and where the possibility of planting trees is small, the integration of variations of the Shadum Evaporatis structure appears to be an efficient way of substituting the functions of real trees (shading and transpiration) and combining them with the spatial experience, which urban squares in Athens should provide during the summer.

Finally, urban design proposals integrating PDEC towers are seen as a way to stimulate further bioclimatic and environmental interventions in the densely built Athens, as well as in other Greek cities. It can also be a way to educate the general public on issues of passive cooling, sustainable, environmentally friendly techniques.

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