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SOLAR ACCESS, PASSIVE COOLING AND MICROCLIMATE IN THE CITY: THE POLIS PROJECT

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ABSTRACT

This paper describes a European project to produce comprehensive design guidance on urban layout to ensure good access to solar gain, daylighting and passive cooling. The project involves:

1. A comprehensive, integrated analysis of all solar and microclimatic aspects of urban layout, including pollution;
2. Development of a major computer based design tool to evaluate solar access and wind patterns within urban configurations in Europe, and simple manual tools to calculate solar access and daylight availability on obstructed sites;
3. Selected case studies, including two major case studies of southern European sites, to test and refine the guidance;
4. Production of an illustrated design guide, papers and presentations communicating the results.

KEYWORDS

Solar energy, microclimate, pollution, site layout, urban planning, daylight, passive cooling

1. INTRODUCTION

POLIS is a research project sponsored jointly by the European Commission's JOULE research programme and by national funding agencies including the UK Department of Environment, Transport and the Regions. It is a three year project which began in January 1996 and is set to end in December 1998.

The research phase, now nearly completed, covers all solar and microclimate aspects of urban layout. The project also includes the development of design tools, case studies to illustrate and inform the results; and production of design guidance. These are described below.

The project includes the following organisations:

- Building Research Establishment Limited
- National and Kapodistrian University of Athens
- LEMA, University of Liege
- University of Seville

2. BACKGROUND

Cities are growing rapidly, and today's cities are increasingly polluted and uncomfortable places to be. Consequently new developments are often planned as 'climate rejecting'- sealed, air conditioned, deep plan, with tinted glass to cut out solar gain and daylight. Such developments may then worsen the local microclimate further; air conditioning results in extra thermal emissions to the surroundings, reflective glass reflects solar heat and glare back out, and large, bulky buildings create hostile local wind effects and overshadow neighbouring buildings which depend on daylight. The result is a vicious circle of worsening exterior environment and spiralling energy costs.

Badly planned urban areas use much more energy for air conditioning in summer and for heating in winter and even more electricity for lighting. The University of Athens has studied the urban heat island effect, obtaining temperature and relative humidity data at twenty locations in the city of Athens in summer 1996. The results have been particularly interesting:

- Very high temperature differences, between 5-15 °C, have been found between the urban and suburban measurement stations during the daytime, especially on hot days. The temperature difference nearly always goes up as the temperature of the urban location increases.
- During the night, the temperature difference between urban and suburban areas is not very important.
- An important difference is found during the night between the National Garden site and the surrounding urban measurement stations. This difference is up to 5 degrees.

These results show that urban microclimate has a tremendous impact on the energy consumption of buildings during summer while the use of green spaces may contribute significantly to decrease urban temperatures during the summer.

Increased urban temperatures also exacerbate pollution by accelerating the production of photochemical smog. The behaviour of pollutants in urban areas has long been a matter of concern. Discharges from industry have come under greater control with the passage of time. However, there has been a growth of other types of polluting discharge, especially from vehicle emissions, so urban pollution levels remain unacceptably high. An alternative strategy aims to modulate the external climate and maximise the use of renewable energies. This involves planning building layout to allow adequate access to solar heat gain and daylighting, and in warmer climates to promote passive cooling. Good urban layout design will also provide an attractive exterior environment, pleasantly sunlit and sheltered from the wind in colder latitudes, cool and shaded in hotter climates in summer, with breezes to disperse pollutants.

For passive solar design in northern latitudes site layout is of particular importance. Because of low solar altitudes careful spacing of buildings is necessary to obtain solar gains throughout the winter, but there are important benefits (typically around 10% of heating energy costs in housing (NBA Tectonics 1988)) because of the long heating season and low external temperatures. Diffuse daylighting is a key strategy in the cloudy climate of northern Europe. The effective exploitation of daylight could lead to energy savings of 3-6 million tonnes of coal equivalent by 2020. To realise the benefits of daylighting, however, urban layout must minimise the problems of obstruction and overshadowing.

3. TOOLS AND TECHNIQUES

Access to daylight and solar gain

To reap the full benefits of passive solar design, winter solar gain should be maximised as far as other site layout constraints allow (Littlefair 1991, 1998). The most important area to keep lightly obstructed is within 45° of due south of a solar collecting facade. (Figure 1). This is the part of the sky from which most solar radiation comes in the winter months. To check whether solar access from this zone is retained, draw a north-south section (not necessarily perpendicular to the facade). The altitude of any obstructions in it should not exceed the critical angle h measured from the centre of the solar collecting glazing.

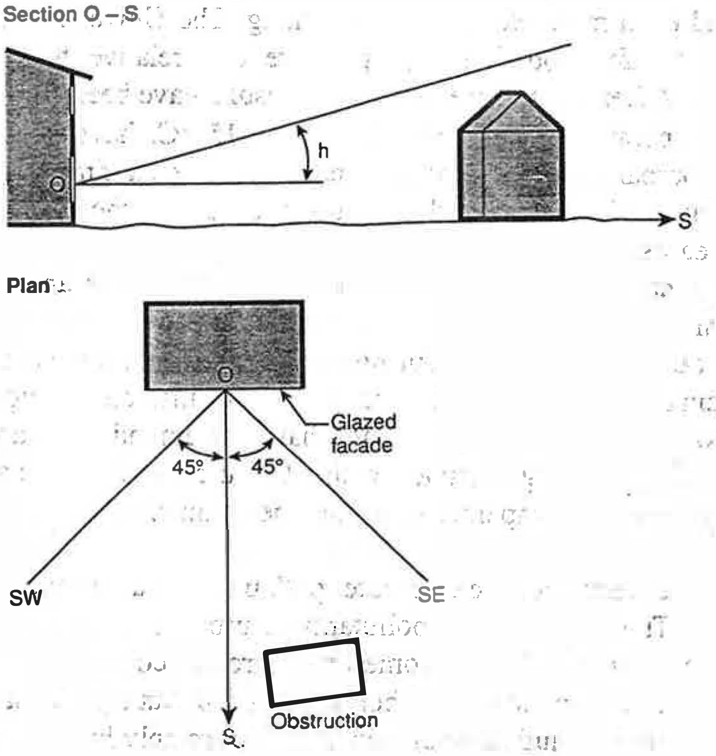

Figure 1 For solar access in urban areas the area of sky between south east and south west becomes important. Obstructions in this zone should ideally not exceed the critical angle h. For latitudes above 50°, h is 70° - latitude; for latitudes below 46.5°, h is 66.5° - latitude; for intermediate latitudes h is 20 degrees.

For diffuse daylighting the requirements are less strict. The simplest technique is an obstruction angle measured from the horizontal. This is appropriate in the initial stages of analysis and for wide, relatively low obstructions like terraced houses. A more flexible method is the use of vertical sky component, defined as the ratio of the direct sky illuminance falling on the vertical wall at a reference point, to the simultaneous horizontal illuminance under an unobstructed sky. Studies in the UK (Littlefair 1991) suggest that an obstruction angle of 25 degrees, corresponding to a vertical sky component of 27% is broadly appropriate. These values tie in well with recommendations by other authors (Evans 1980). BRE have developed a method to generate similar criteria for other daylighting climates. A flexible approach is required which takes into account the needs of the development and its surroundings. An adapted technique can be used to establish the loss of daylight to existing buildings nearby, an important design issue.

Wind tunnel studies

The project also includes wind tunnel studies of the dispersion of local pollutants to allow natural ventilation of buildings and improvement of the outdoor environment. This includes the ventilation of contaminants from courtyard wells. The experiments are planned to cover a wide range of courtyard depths, down to quite shallow structures. Results indicate very low rates of pollutant dispersal from the lower parts of deeper enclosed courtyards. CFD modelling (Coronel and Alvarez 1998a) agrees with this. Another wind tunnel model is presently planned to investigate contaminant dispersion within the Pireas case study area.

This work is being backed by the University of Athens who have carried out experiments to study ventilation through urban canyons (Santamouris et al 1998). These started in early November 1996. In the experiments the following are measured:

* Wind velocity and direction on top of the buildings forming the canyon. The sensor is located where the wind flow is effectively undisturbed by the presence of buildings.
* Wind velocity at various heights inside the canyon.
* The air temperature at various heights.

The results show that temperatures can vary considerably within the canyon at different times of day, depending on sunlight penetration and the presence of traffic. The albedo of the building materials also has a big impact on surface temperatures.

Influence of heat sinks

The University of Seville have carried out work on modelling the cooling effects of, for instance, a river, a lake or an urban park on the surrounding areas. This cooling effect takes place when hot air is put into contact with a surface at a lower temperature. The vegetation and the water are able to maintain a lower temperature due to the evaporation that acts as a regulatory mechanism. The approach consists of a simulation using CFD codes, and comparison with the results of actual experiments. These have been used to generate a set of functions and graphs that give the reduction in air temperature when the air passes over a cooler area.

Design tools

Design tool development has concentrated on extending LEMA's sophisticated TOWNSCOPE software (Dupagne 1991, 1998) to produce an integrated tool to model sunshine, wind and daylight in urban areas. The original TOWNSCOPE had evaluation modules on availability of solar radiation, heating needs, theoretical energy consumption (for housing only), cost calculations, 3D visualisation, indoor comfort and wind effects (only a rough estimation of the average wind speed at any level). Under the POLIS project new evaluation modules will include wind effects on comfort in outdoor spaces and building energy losses, daylighting in buildings, diffuse solar radiation and ground reflected radiation, and improved cost calculations.

Simple manual tools to evaluate loss of daylight, sunlight and solar gain due to obstructions have also been produced (Littlefair 1997).

Case studies

The research is backed by a series of case studies of urban areas, including two extended studies of Mediterranean sites (Coronel and Alvarez 1998b). Short case studies, both real and theoretical, investigate different design issues in different parts of Europe.

LIST OF CASE STUDIES

Location	Country	Type	Key issues	Partner
Pylea, Thessaloniki	Greece	Extended	Daylighting, cooling load, large estate design	Athens
Santa Cruz, Seville	Spain	Extended	Refurbishment of historic area, shading, pedestrian comfort	Seville
Lisboa	Portugal	Short	Solar radiation, shadowing, comfort	Seville, LEMA
Liege	Belgium	Short	Low cost housing, passive solar gains	LEMA
Liege	Belgium	Short	City edge areas	LEMA
Pennyland, Milton Keynes	UK	Short	Passive solar access, estate layout, trees	BRE
EXPO site, Seville	Spain	Short	Passive cooling (fountains etc) for comfort	Seville
Piraeus harbour	Greece	Short	Warm climate issues	Athens
Various	-	Theoretical	Cooling loads	Seville

The northernmost study is of the Pennyland Estate, Milton Keynes, an estate of 177 passive solar houses, built in 1980. 134 of the houses face due south and all have high insulation and passive solar direct gain through glazing. A survey of the site revealed interesting findings. The estate's informal layout and luxuriant planting has completely avoided the regimented appearance commonly associated with passive solar layouts. Only the window sizes give any clue that this is a passive solar estate. However privacy is an issue and there is widespread use of net curtains which may cut solar gains. Also growth of shrubs and trees has resulted in some loss of winter solar access. A survey has been carried out to quantify this loss. At midday in January 3% of the houses had more than half their south facing glazing in shadow, while a further 9% had between 25% and 50% in shadow. The most common cause of overshadowing is by planting.

4. CONCLUSIONS

Urban layout planning can have a major impact on the external environment and on the performance of buildings within it. The POLIS project aims to give guidance on how to produce comfortable, energy efficient buildings surrounded by pleasant outdoor spaces, reducing energy consumption and the effects of pollution.

The major output of the research will be a draft design guide, to include guidance on all the issues addressed. This will be supplemented by the following:

- TOWNSCOPE software with user manual;
- Book of indicators for manual prediction of solar access in the EU
- Fully illustrated case study document

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The following papers are being presented at the POLIS workshop at the EPIC98 conference:
Dupagne A, Desmecht J, and Teller J, (1998), 'TOWNSCOPE- a project information system for energical sustainability design review'.
Santamouris M et al (1998) 'Energy in the Urban Environment: the case of Athens'
Coronel J F and Alvarez S (1998a), 'Characterization of air flow patterns in courtyards'
Coronel J F and Alvarez S (1998b), 'Oasis effect in Santa Cruz district. Experimental results and thermal simulation'