

Natural Techniques To Improve Indoor And Outdoor Comfort During The Warm Period – A Review

Matheos Santamouris

Group Building Environmental Studies, Physics Department, University of Athens, Athens, Greece. E-mail : msantam@phys.uoa.gr

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Abstract

The present paper discusses the actual state of the art of the existing natural methods and techniques to improve outdoor thermal comfort in buildings during the warm period. The latest developments regarding the methods to improve the thermal conditions in the urban environment are discussed. In parallel, selected information of heat dissipation techniques is given.

Introduction

Increased living standards in the developed world using non-climatically responsive architectural standards have made air conditioning quite popular. Importantly, this has increased energy consumption in the building sector. Actually there are more than 240 million air conditioning units and 110 heat pumps installed worldwide according to the International Institute of Refrigeration (IIR) (IIR, 2002). IIR's study shows that the refrigeration and air conditioning sectors consume about 15% of all electricity consumed worldwide (IIR, 2002). In Europe it is estimated that air conditioning increases the total energy consumption of commercial buildings on average to about 40 kWh/m²/year.

There are different problems associated with the use of air conditioning. Apart from the serious increase of the absolute energy consumption of buildings, other important impacts include:

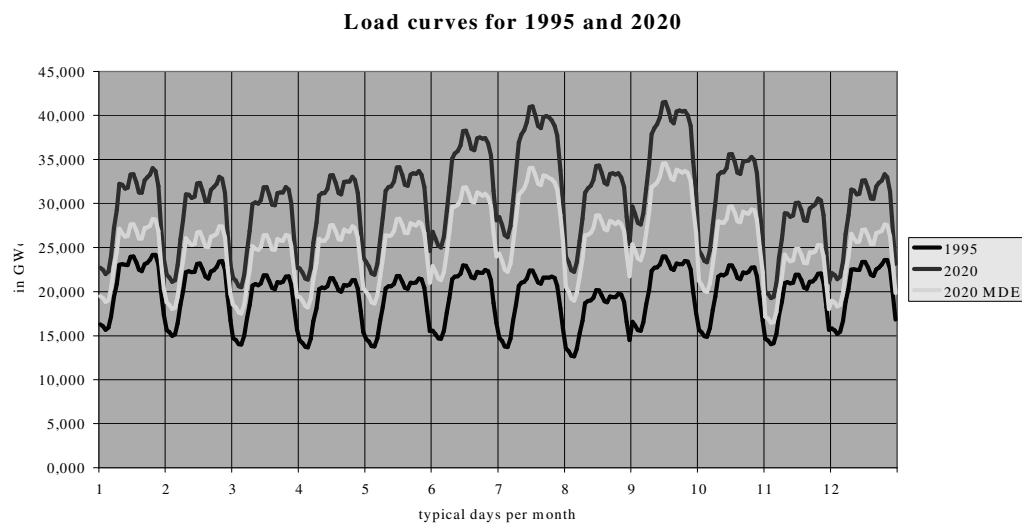
The increase of the peak electricity load;

Environmental problems associated with the ozone depletion and global warming;

Indoor air quality problems.

High peak electricity loads oblige utilities to build additional plants in order to satisfy the demand, but as these plants are used for short periods, the average cost of electricity increases considerably. Southern European countries face a very steep increase of their peak electricity load mainly because of the very rapid penetration of air conditioning. For example, Italy faced significant electricity problems during the summer of 2003 because of the high electricity demand of air conditioners. Actual load curves for 1995 and the expected future peak electricity load in Spain, are given in Figure 1 (Adnot, 1999). It is expected that the future increase of the peak load may necessitate doubling installed power by 2020.

Figure 1. Load curves for 1995 and 2020 in Spain, (Adnot 1999)



Addressing successful solutions to reduce energy and environmental effects of air conditioning is a strong requirement for the future. Possible solutions include:

1. Adaptation of buildings to the specific environmental conditions of cities in order to efficiently incorporate energy efficient renewable technologies to address the radical changes and transformations of the radiative, thermal, moisture and aerodynamic characteristics of the urban environment. This involves the use of passive and hybrid cooling techniques to decrease cooling energy consumption and improve thermal comfort.
2. Improvement of the urban microclimate to fight the effect of heat island and temperature increase and the corresponding increase of the cooling demand in buildings. This may involve the use of more appropriate materials, increased use of green areas, use of cool sinks for heat dissipation, appropriate layout of urban canopies, etc.

Passive cooling techniques in buildings have proven to be extremely effective and can greatly contribute in decreasing the cooling load of buildings. Efficient passive systems and techniques have been designed and tested. Passive cooling has also proven to provide excellent thermal comfort and indoor air quality, together with a very low energy consumption

Passive cooling techniques can be classified in three main categories, (Santamouris and Assimakopoulos, 1996):

- a) Solar and Heat Protection Techniques. Protection from solar and heat gains may involve: Landscaping, and the use of outdoor and semi-outdoor spaces, building form, layout and external finishing, solar control and shading of building surfaces, thermal insulation, control of internal gains, etc.
- b) Heat Modulation Techniques. Modulation of heat gain deals with the thermal storage capacity of the building structure. This strategy provides attenuation of peaks in cooling load and modulation of internal temperature with heat discharge at a later time. The larger the swings in outdoor temperature, the more important the effect of such storage capacity. The cycle of heat storage and discharge must be

combined with means of heat dissipation, like night ventilation, so that the discharge phase does not add to overheating.

- c) Heat dissipation techniques. These techniques deal with the potential for disposal of excess heat of the building to an environmental sink of lower temperature. Dissipation of the excess heat depends on two main conditions: 1) The availability of an appropriate environmental heat sink; and 2) The establishment of an appropriate thermal coupling between the building and the sink as well as sufficient temperature differences for the transfer of heat. The main processes of heat dissipation techniques are: ground cooling based on the use of the soil, and convective and evaporative cooling using the air as the sink, as well as water and radiative cooling using the sky as the heat sink. The potential of heat dissipation techniques strongly depends on climatic conditions. When heat transfer is assisted by mechanical devices, the techniques are known as hybrid cooling.

Improving the Urban Microclimate

Increasing urbanization has deteriorated the urban environment. Deficiencies in development control have seriously impacted the urban climate and environmental performance of urban buildings. As reported by Akbari, New York City has lost 175,000 trees, or 20% of its urban forest in the last ten years (Akbari et al, 1992).

As a consequence of heat balance, air temperatures in densely built urban areas are higher than the temperatures of the surrounding rural country. This phenomenon known as 'heat island', exacerbates electricity demand for air conditioning of buildings and increases smog production, while contributing to increased emission of pollutants from power plants

Important research has been carried out during the recent years to mitigate heat island. The development of cool materials for the urban environment seems to be one of the more promising developments. Cool materials present a very high reflectivity and a very high emissivity as well. Cool materials with lower emissivity have been developed as well.

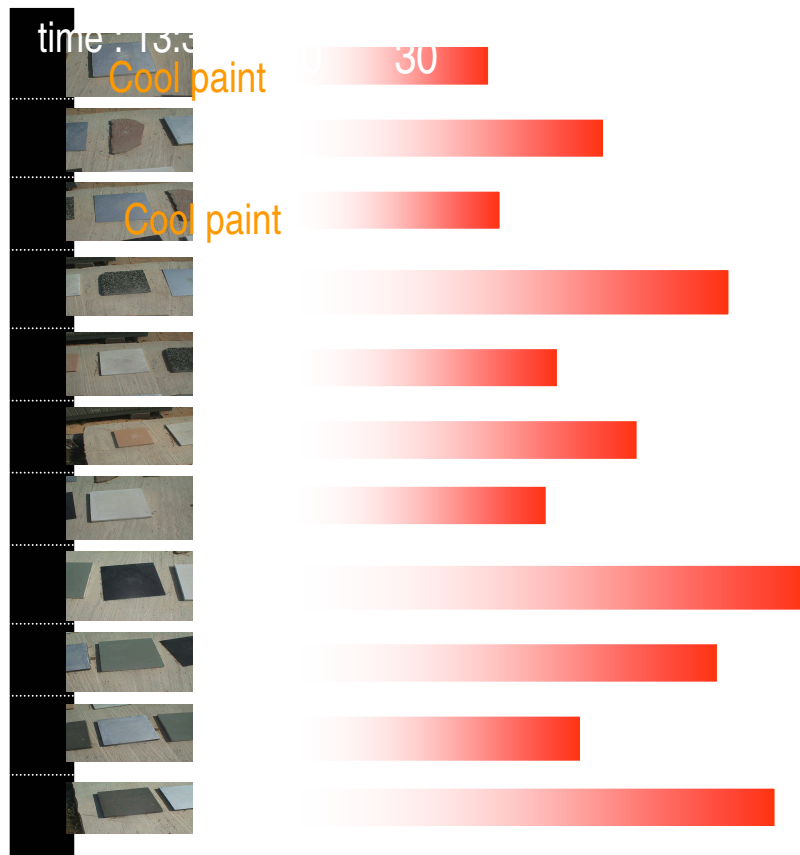
There are a number of cool materials currently commercially available for buildings and other surfaces of the urban environment like cool surface coatings (elastomeric, acrylic etc.), cool single ply membranes, reflective tiles, metal roofs, light colored marble and mosaic, concrete and conventional asphalt with white aggregate. All the above-mentioned materials are white or light coloured (Berdahl P. et al. 1997, Akbari et al. 2001, Doulos et al. 2004, Synnefa et al. 2005).

As shown by Synnefa et al, 2005, white cool materials present almost 5 C lower temperature compared to white marbles, (Figure 2). As it concerns the impact of emissivity, it has been concluded that reduction of emissivity from 0.9 to 0.5 may increase the night temperature by 3-4 C.

Cool nonwhite materials have been developed as well during recent years. A cool nonwhite coating that absorbs in the visible range should be highly reflective in the near infrared part of the electromagnetic spectrum to maintain a high solar reflectance. Cool colored coatings can be applied on building envelopes and other surfaces of the urban environment as exterior finishes and paints or they can be used to manufacture building materials that reflect more sunlight than conventionally pigmented products.

Figure 2. Peak daytime temperatures of various materials used for pavements.

Materials 1 and 3 are cool materials.



In order to help manufactures optimize the solar reflectance of a pigmented coating matching a particular color and improve the performance of cool colored building materials compared with standard products, scientists have identified and characterized the optical properties of a large number of pigments creating a database of pigment characteristics, classifying them as ‘cool’ or ‘warm’. (Levinson et al. 2005, Levinson et al. 2005B). In the framework of a research program supported by the California Energy Commission several engineering methods have been developed to apply cool coatings to roofing materials (clay tiles, concrete tiles, metal roofs and shingles). More specifically a palette of cool non-white coatings was developed for concrete tiles the solar reflectance of which exceeds that of a color matched conventionally pigmented coating by 0.15 to 0.37. The cool colored clay tiles developed had a solar reflectance over 0.4. In general, the solar reflectance of commercially available roofing products has increased to 0.30-0.45 from 0.05 –0.25 for all materials except shingles whose solar reflectance exceeds 0.25 (Akbari et al. 2005). Furthermore, Kinouchi et al. (2004) have developed a new type of pavement that satisfies both high albedo and low brightness based on the application of an innovative paint coating on conventional asphalt pavement. The pigments and coating structure used are effective in achieving low reflectivity in the visible part of the spectrum (23%) and high near infrared reflectivity (86%). Field measurements show

that the maximum surface temperature of the paint coated asphalt pavement is about 15°C lower than that of the conventional one.

In Syneffa et al, (2006), 10 prototype cool colored coatings were created, using near infrared reflective color pigments, and tested in comparison to conventionally pigmented color matched coatings. The spectral reflectance and the thermal performance of the coatings were evaluated. The cool colored coatings have the same visible reflectance with the standard coatings but they exhibit a more selective absorption band in the infrared part of the spectrum reflecting large parts of the solar energy that arrives as infrared radiation rather than absorbing it. This results to lower surface temperatures for the cool colored coatings. The maximum difference between the solar reflectance of a cool and standard colored coating was found to be 22 C with a corresponding temperature difference of 10.2°C, for summer conditions. It was also found that natural exposure of the samples for three months had an impact on the solar reflectance of the samples but did not significantly affect their infrared emittance values.

Heat Dissipation Techniques

Heat dissipation techniques are based on the transfer of a buildings' excess heat to a low temperature environmental sink. Main sinks are the ambient air, water, the ground and the sky. When heat is dissipated to the ambient air, the technique is known as 'convective cooling;' when water is used the process is known as 'evaporative cooling;' when the ground or the sky are the sinks, the techniques are known as 'ground and radiative cooling' respectively

Extensive experimental and theoretical studies investigating techniques and methods to improve natural ventilation efficiencies as applied in dense urban areas, were conducted by the European research project URBVENT, (Ghiaus et al, 2003). Algorithms to calculate the wind speed in urban canyons as a function of the undisturbed wind speed above the buildings, as well as methodologies to assess the potential of natural ventilation in some hundreds of thousands configurations of urban buildings have been developed and experimentally validated (Santamouris, 2003b). Intelligent software tools based on neural networks that permit estimates of required opening areas required in order to achieve a defined air flow, have been developed and are currently available.

Hybrid ventilation use both natural ventilation and mechanical systems with different features of these systems at different times of the day or season of the year and within individual days to provide a comfortable internal environment (Heiselberg, 2002). Hybrid ventilation systems are based on an intelligent control system than allows switching between natural or mechanical modes in order to minimize energy consumption.

Different hybrid ventilation systems have been proposed and applied in various types of buildings. An extended review of these systems and their existing applications is provided by (Delsante and Vik, 2001).Results from first generation hybridly ventilated buildings, show that such techniques have great potential. Hybrid systems were found to be quite effective in providing good IAQ and thermal comfort, while the energy performance was good but not excellent. Hybrid ventilation is proved to be suitable for schools and cellular offices while in open- plan offices there were some complaints. Hybrid ventilation is a very new and promising technology but several

problems still remain. Design tools and methodologies as well as more robust control strategies and sensors for demand control ventilation must be developed in the future.

Conclusions

During the last few years important basic and industrial research has been carried out that has resulted in the development of new high-efficiency materials, systems, tools and techniques. However, the continuing increase of energy consumption of air conditioning suggests a more profound examination of the urban environment and the impact on buildings as well as to an extended application of passive cooling techniques. Appropriate research should aim at better understanding micro-climates around buildings, and to understand and describe comfort requirements under transient conditions during the summer period. Also of importance are improving quality aspects, developing advanced passive and hybrid cooling systems, and finally, developing advanced materials for the building envelope.

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