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Natural ventilation in residential buildings in Athens: Results of field study on occupants' behaviour & perception of thermal comfort.

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Abstract

This paper discusses the potential for natural ventilation for the south suburbs of Athens, in the summer months when the use of air-conditioning is on the increase, not only as an alternative proposal to air conditioning but also as an effective strategy that can improve indoor air quality, provide comfort, and decrease unnecessary energy consumption. Natural ventilation is a commonly used principle for ventilating buildings, not only providing fresh air for the occupants but also for cooling in cases where climatic conditions allow it, because of the direct influence of thermal comfort sensations experienced by the occupants. The field study presented aims to demonstrate that in houses of a similar type, thermal comfort results can vary as result of the occupants' habits and use of space. The study highlights interesting variables affecting the internal temperature and thermal comfort of the occupants and highlights the potential that naturally ventilated buildings have in achieving a satisfying level of thermal comfort. Conclusions are drawn on the above.

Keywords: Natural ventilation, air-conditioned, thermal comfort, Mediterranean climate

1.1 Introduction

Natural ventilation is a commonly used principle for ventilating buildings and can be used not only to provide fresh air for the occupants but also for cooling in cases where climatic conditions allow it, because of the direct influence on thermal comfort sensations experienced by the occupants. It relies on wind and thermal buoyancy as driving forces and it can be controlled by openings in the building, which can either close or open depending on the internal needs.

Athens, like most urban centres, suffer from the urban island effect and the number of hours that the temperature is above 37°C to 40°C is increasing every year with alarming consequences for the energy consumption as well as the quality of life. Since natural ventilation efficiency is affected by the local climate and wind conditions it is reasonable that in a climate like the Mediterranean, the potential for natural ventilation is examined as an alternative to mechanical ventilation as a correlation exists between comfort and natural ventilation on the particular geographical location. There are many factors shaping the relationship between human bodies and their immediate environments and the mechanical control of ambient thermal conditions is playing an increasingly important part. It can be argued that the use of air-conditioning has created a culture: the culture of living indoors. An average person today spends about 90% of his time indoors. Greece in particular presents one of the higher figures concerning the average cooled-floor area per inhabitant for EU countries and is continuously increasing, according to the Energy Efficiency and Certification of Central Air Conditioners Studies (EECCACC study, 2003). High

penetration of air conditioning in the building sector increases the absolute energy consumption of the sector and the corresponding carbon dioxide emissions, highly increases the peak electricity demand during the summer period and adds to the rising external temperatures.

This paper looks at the potential for natural ventilation in apartment blocks in the south suburbs of Athens in the summer months when the use of air-conditioning is on the increase, not only as an alternative proposal to air conditioning but also as an effective strategy that can improve indoor air quality, provide comfort, and decrease unnecessary energy consumption.

1.2. Natural ventilation

Natural ventilation characteristics can be described as three components. The first is the natural force used to drive the ventilation; this can be wind, buoyancy or both. The second aspect is the principles used to ventilate a space which can be cross ventilation, single sided or stack ventilation. The third component is the element or device used to realise the ventilation, which for example, can be windows, openings, wind towers, atria, chimneys or ducts. Considering that natural ventilation is a climatic factor, a renewable alternative, as well as an important source of comfort, it seems to be relevant to consider its great potential when applied to architecture, taking into account economical and environmental gains.

1.3. Thermal comfort & standards

Human thermal comfort is defined by ASHRAE as the state of mind that expresses satisfaction with the surrounding environment (ASHRAE Standard 55 (2004). The definition goes further to say that comfort is the absence of thermal discomfort and a condition in which 80% of people do not express dissatisfaction. Nevertheless it is not a perfect description when translated into physical parameters as it also involves physiologic, psychological and subjective considerations. People can feel thermal comfort in different thermal environments. Consequently, an absolute standard of thermal comfort does not exist. This is only reasonable considering that humans can live in a range of different climates, varying from the tropics to high latitudes. Researchers have been exploring ways to predict the thermal sensation of people in their environment based on the personal, environmental and physiological variables that influence thermal comfort.

2. Research methods

For the field study, five residential houses were monitored in relation to the internal and external temperatures for 35 days during the summer of 2011.The monitoring period was from 15th July to 20th August 2011 as July is the warmest month and August is the month that the Etesian winds blow more strongly. The recordings relate to temperature, both indoors and outdoors and were taken at different floor heights and orientations. Post occupancy questionnaires were collected as well as electricity energy consumption readings for the monitoring period. Variables of interest include the use or not of air-conditioning, dwelling age and orientation, insulation levels and external weather but also the age and preferences of occupants.

2.1. Field study

The monitoring was done through temperature loggers (i-buttons), questionnaires and

the recording of energy consumption. The number of dwellings monitored is small however the i-buttons were placed in different rooms, orientations and floor heights and therefore the analysis provides interesting conclusions. Forty-five i-buttons (nine in each property) were used for the monitoring, fourteen of which located in external locations, mainly balconies and pilotis. The period monitored is characteristic of the summer season and includes the typically warmer period. It should be noted there is a small number of responses to the questionnaires which is not statistically significant; nevertheless the responses give an indication of the characteristics of the occupants, their preferences and living patterns.

2.2. Questionnaires

The information collected from the questionnaires was provided by the occupants. One questionnaire was completed per household. In most cases it was possible to query the occupants for additional information; however the accuracy of the responses depends on the experience of the occupant of each property. The questionnaire has a quantitative part to answer questions such as who, how much, and how many. The qualitative part is used to answer questions such as how and why and provide the author with the perspective of the occupants through direct interaction with them. The interview was not being limited to a set of predetermined questions to be asked in sequence. This allowed the occupants to provide their own explanations in a participatory exchange with the interviewer (author).The information collected from the questionnaires relates to:

- Age/type/orientation/construction/refurbishment details/air-conditioner details.
- Age/comfort levels/occupancy pattern of residents.
- Their use of either natural or mechanical ventilation during this period.

Responses highlight that occupants may use air-conditioners at some times but at other times use an adaptive comfort approach (such as opening a window, wear lighter clothing etc) to cope with the hot weather. Responses also indicate that the adaptive comfort approach is preferred in some cases as well as is considered as an opportunity to make energy savings.

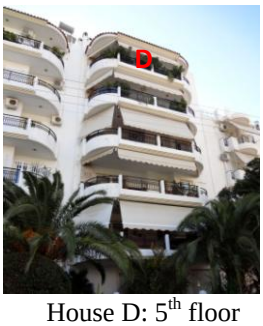
2.3. Location & characteristics of residential homes monitored

All the houses are apartments in typical block of flats and are located in the southern part of Athens, to relatively close proximity to the sea. House A is a ground floor apartment in a 2-storey building. Across the street from house A, houses B and C are located which are part of the same 3-storey building. House D is further south but in a walking distance from the other houses and is located in a 5-storey building. House E is located in close proximity to the sea and a 20 minutes driving distance from the other dwellings.

House A: ground floor

House B: 3rd floor (top)

House C: 1st floor



House D: 5th floor (top)

House E: 4th floor

The apartments are between 80m² to 180m² with balconies or garden when on the ground floor. 80% have a pilotis and are located in different floor heights .Three are between 30 to 33 years old, one 21 years old and one 13 years old. This difference in the age of construction affects the envelope details as buildings built before the 1980s generally are not insulated. Most of the buildings of the period 1980–2000 are partly or insufficiently insulated and buildings after 2000 are considered completely insulated according to the first Hellenic building thermal insulation regulation (HBTIR). 80% prefer natural ventilation as opposed to air-conditioning and only the 20% (1 home) prefer to use air-conditioning, however all apartments have between two and four air-conditioner units located in different rooms. One occupant (House E) did not use air-conditioners for the monitoring period. All apartments generally have sliding glazed doors to gardens and balconies which typically have external shading panels and a canopy above. All but one apartment have awnings around the balconies which were kept lowered for most of the monitoring period.

3. Results and findings of field study

The week from 08/08/11 to 14/08/11 has the highest external temperature range (approximately 24°C to 33°C). Looking at the climate bulletins for that period and the general predicted temperatures this can be the result of a northern wind cooling the air.. The period from 19/7/11 to 26/07/11 also presents a variation in temperatures of a range between 25°C to 34°C which is selected to examine the variations in indoor temperatures on a diurnal basis.

The results of the temperature readings combined with the responses from the questionnaires and the knowledge of the people's occupancy patterns, leads to the conclusion that people have different perception of thermal comfort. Therefore, setting the a/c in one temperature that is considered 'comfortable' will not necessarily satisfy all occupants. When asked questions relating to their comfort sensation when using a/c or natural ventilation only, occupants generally felt a/c feels cooler. Also, the air was considered rather humid when using natural ventilation while more neutral when the a/c was working. Higher levels of humidity can add to the feeling of thermal discomfort. A/C units dry the air, which can add to the feeling of coolth perceived by the lower indoor temperature. Natural ventilation is ineffective at reducing the humidity of incoming air in humid climates, but in a climate like Athens, there is still potential for taking advantage of buoyancy caused by temperature and humidity.

The occupants recorded their electricity consumption from the 15/07/11 to 30/08/11. Although the electricity accounts for other appliances such as fridge, washing machine, lighting, television and computers, it can give an overview of the consumption. The house (house E) that uses natural ventilation has the lowest consumption and with a big difference. House D has the highest consumption, more than double of the other properties. When these values are compared to KWh/m², house C at first floor consumes less as the occupants are keener on adapting to the external temperatures to avoid using a/c. The response from the questionnaire also highlight that occupants may use air-conditioners at some times but at other times use an adaptive comfort approach (such as opening a window, wear lighter clothing etc) to cope with the hot weather. It is obvious that the use of a/c has a direct impact on the electricity bills, energy use and as a result on the CO2 emissions. Ir was also noted that orientation and floor height as well as the building envelope affected the temperatures inside a house.

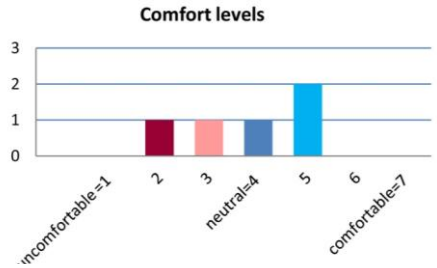


Figure 1: Occupants comfort sensation in relation to indoor temperature for the monitoring period in general. It is interesting that these were the occupants of house A and house E. The occupant of house E uses only natural ventilation and is comfortable to higher temperatures than most of the other occupants.

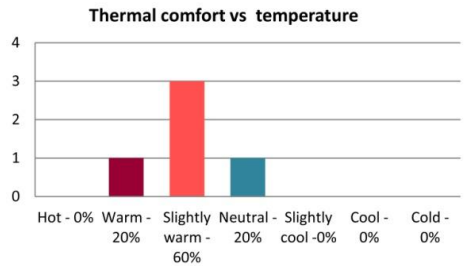


Figure 2: Occupants thermal comfort sensation in relation to indoor temperature for the monitoring period in general. The houses where the occupants felt slightly warm are house C which is one of the warmest, house D that occupant prefer a/c most times and house E which uses natural ventilation. This shows the range in people's perception of comfort.

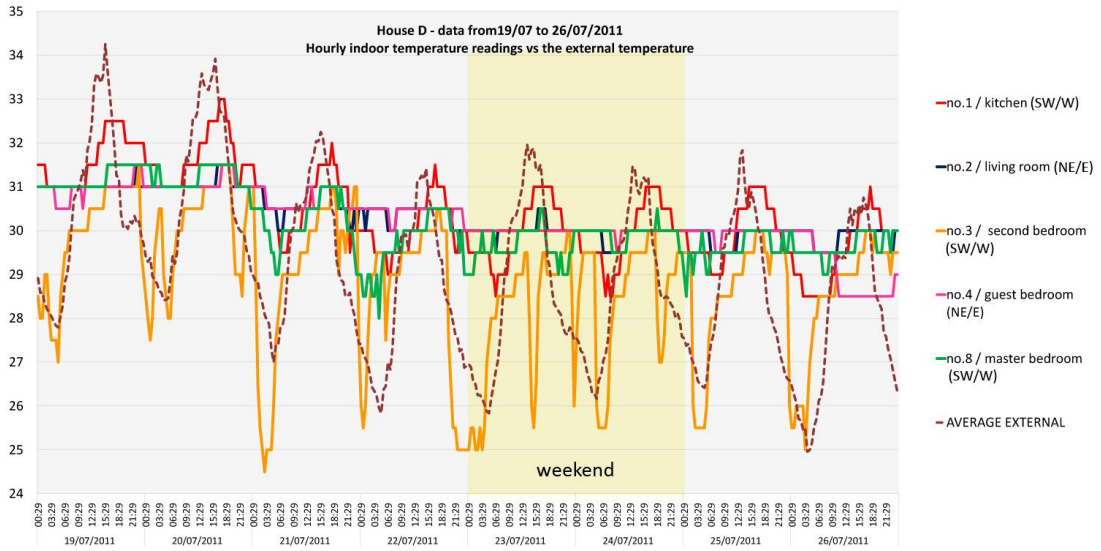


Figure 3: Table showing the variation on the internal temperatures vs the external temperature for House D for the week 19/07 to 26/07/11. This house mainly used a/c for the study period.

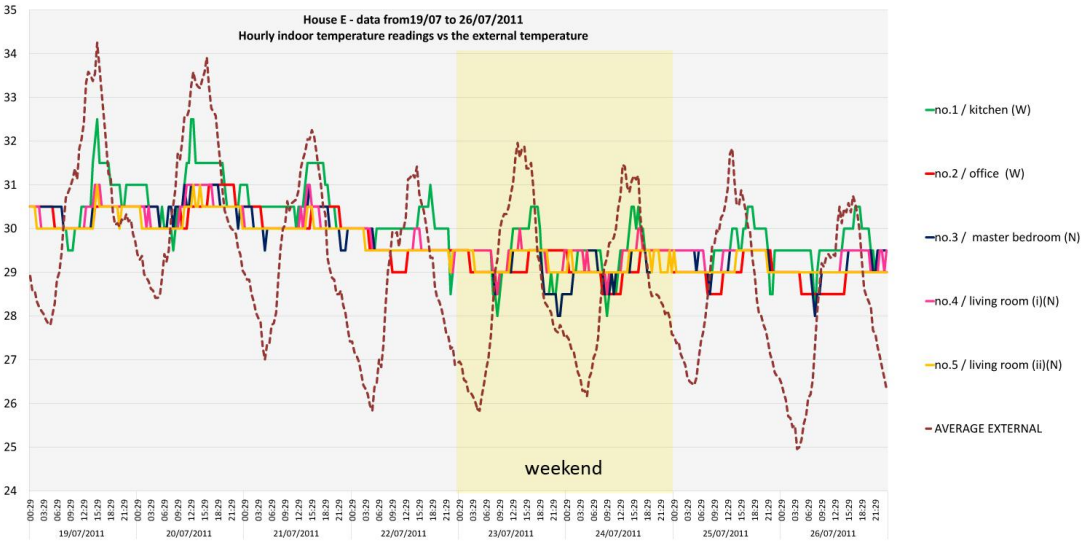


Figure 4: Table showing the variation on the internal temperatures vs the external temperature for House E for the week 19/07 to 26/07/11. This house only used natural ventilation for the study period.

4. Conclusion

Looking at the results and analysis of the case studies this research suggests that this is possible to use natural ventilation in the south of Athens and provide thermal comfort. The use of a/c can greatly be reduced with the use of natural ventilation although it might still be deemed necessary to use a/c at extreme temperatures (heat waves). One of the conclusions is that the potential for natural ventilation for comfort in these apartments generally relies on mixed mode approaches that use natural ventilation for most of the summer, and mechanical cooling for peak periods. This conclusion is taking into account the particular occupants' thermal comfort sensation and expectations. The analysis of the case studies demonstrated that it is not easy to define an exact set of parameters as an ideal thermal comfort environment for all occupants. Comfort of a space is dependent on many variables such as the temperature, the amount of fresh air, the movement of air, the humidity etc. It also changes depending on what the occupants are doing, their age, habits and preferences. It is possible for the occupants to move during the day according to which room is the cooler and avoid using a/c. There is also potential to use natural ventilation to cool and provide thermal comfort most of the days of the summer. Mixed mode may be used at times that the temperature peaks to extremes. Shading and design in this location, which takes into account urban canyons, prevailing winds directions and air flows can significantly provide sensation of comfort through the air movement as well as cool the air.

5. Discussion

People have different perceptions of thermal comfort, however they can adapt to different temperatures. If the rise in the use of a/c became the norm over time, potentially this mentality can shift again in favour of natural ventilation. This can mean that they could take the potential to adapt to the local climate and to higher temperatures. Occupants can alter their behaviour and be active users of a naturally ventilated building. Physiological and behavioural adjustment may lead to a greater tolerance for temperature variation.

Taking the above point into consideration, it can be said that a naturally ventilated apartment can achieve temperatures within the occupant's comfort range most times. It is not as easy to achieve the above point on a retrofit of an existing building. Elements like shading (awnings, vegetations) can be utlised to protect the envelope from direct sunlight. Balconies, wind breakers and other building element can help the occupants take advantage of the local climate potential. Also important is to indicate to the occupants the ways in which they can actively control their environment.

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