Using Wind Catchers as a Passive Cooling System for Residential Buildings in Cyprus

H. Altan[1,*] and M.B. Tabriz[1]

[1]Building Environments Analysis Unit (BEAU), School of Architecture, Sheffield University, Sheffield, UK

ABSTRACT
Reducing energy consumption in the built environment is the most important challenge in the world during the recent decades. The rapid increase of energy consumption in the building sector in most countries are making architects to develop methods for designing buildings which use low energy in different climates. Studying traditional buildings in Cyprus would be useful for architects to get the idea of designing vernacular modern buildings. One of the most important factors to achieve thermal comfort especially in countries with hot climate such as Cyprus is ventilation. Wind towers are traditional cooling systems and are one of the characteristics of vernacular architecture in hot regions such as Iran and the Middle East.
As residential buildings are one of the major consumers of the energy use in Cyprus and wind catchers have never been incorporated in any of the building design in the country, this study has focused on the application of wind catchers to the modern residential buildings in Larnaca, Cyprus to recognise whether this design feature is useful in terms of decreasing indoor temperatures and achieving comfort level in residential buildings. Accordingly, the climate of Cyprus has been studied and the traditional buildings have been discussed. Moreover, the traditional architecture and wind towers in Iran have been reviewed. Furthermore, a wind catcher has been applied to an existing modern building in Larnaca and a series of computer simulations have been conducted to analyse the indoor temperatures inside the building before and after applying a wind catcher by using Ecotect and WinAir software.

KEYWORDS
Residential building, Wind catcher, Indoor environment, Ecotect, Thermal comfort, Cyprus

INTRODUCTION

Reducing energy consumption and the effects of global warming on the built environment are the most important challenges confronting the planet. Buildings are major energy consumers in the world. Most twenty first-century buildings around the world are dependent on air conditioning systems and electricity, which rely on fossil fuels. In contrast, vernacular architecture is more adaptable to the environment in hot or cold climates. A well-designed building will be comfortable in summer and energy efficient in winter, and will need little energy input to achieve comfort level (Dunster et al. 2008). Studying traditional techniques to understand sustainable strategies, especially in arid central Iran, could be a valuable contribution to the field. Among all vernacular design strategies for passive cooling in hot-dry and hot-humid climates, wind catchers have made a special appearance in the design of residential buildings. In the study, the aim is to apply a wind catcher to an existing modern building that is located in a coastal city of Larnaca in Cyprus. Most contemporary buildings in Larnaca need air conditioners during hot summers to make the space cooler, which is not

* Corresponding author email: h.altan@sheffield.ac.uk

energy efficient, so passive cooling systems within buildings may be worth considering. Since wind catchers have not been used in Cyprus yet, and because residential buildings in the country need cross-ventilation, using wind catchers as well as appropriate materials may be a good idea for the climate of Cyprus, and therefore the study focuses on passive cooling systems, especially wind catchers, in this particular country.

The main objectives are to find the extent to which passive cooling systems are viable and useable, and to discover how big a reduction in reliance on wind catchers and appropriate materials will be achieved if these systems are applied in modern buildings in Cyprus.

METHODOLOGY

In the study, a series of computer simulation studies have been undertaken with a computer-simulated model of the case study building, to estimate the effect of applying wind catchers in a modern building in Cyprus in terms of energy performance and thermal comfort of occupants. For this, computer-simulated models of a residential building in the city of Larnaca, Cyprus, have been developed, based on the data on building geometry, components and weather. A modelling programme has been chosen from Ecotect and WinAir 4 for thermal analyses and airflow respectively.

In the simulation studies; firstly, the existing situation of the building with existing materials were analysed, then one type of wind catcher, the most appropriate one in the hot climate of Yazd in Iran, were applied. Secondly, the computer model was used for thermal performance analysis and air movements, to understand whether wind catchers would be generally useful for modern buildings in Cyprus. Finally, the materials of the building have been changed, according to the vernacular appropriate materials, which were applied in traditional buildings in in the country.

CYPRIOT TRADITIONAL HOUSES

Traditional dwellings in Cyprus include open, semi open and closed spaces from south to north. In order to understand the logic behind the traditional architecture, these forms should be identified. Closed spaces were built for particular needs such as privacy for family members and protection from severe environmental conditions. The semi closed and open spaces were mainly used for all daily activities. The semi closed spaces act as a traditional area to congregate. Not only it is a place for circulation, but also it is used for leisure activities and domestic uses. Most of these transitional spaces have arcaded facades. The arcaded transitional space between indoor and outdoor produces shade to the south wall as well as provides passive cooling and shadowy area in summer for daily activities and allows the sun comes inside during winter (Dincyurek and Turker 2006). The porch is a semi open space which is located in the middle of the courtyard, a multi functional room, depot and the kitchen. In multi functional rooms a number of activities such as serving guests, cooking, gathering, eating and sleeping can be happen. Another important feature of the traditional dwellings is the depot. The depot is a place which necessary seasonal foods, products and equipment are stored. Next to the depot is kitchen, where the food is prepared and dishwashing is carried out. Moreover, this room is used as a bathroom since water needs to be heated for washing purpose. All these rooms open to the porch. In these kinds of traditional houses the courtyard is used for different activities such as growing vegetables, preparing food for winter, making local cheese, cooking and eating meals, washing clothes resting and gathering together.

CASE STUDY BUILDING

In the study, to apply a wind catcher to a residential building in Cyprus and to modify existing materials, in order to investigate whether this is a good solution to the problem of providing passive cooling and high-quality indoor air for houses, and, consequently, a way of reducing building energy consumption.

The case study is a two-storey residential building located in the city of Larnaca in Cyprus. It was built almost five years ago. The ground floor's dimensions are 14.95m × 14.85m and the first floor has dimensions of 11.90m × 14.85m. The rooms' height is approximately three metres on each floor. There are one bedroom, a kitchen and a living room on the ground floor and three bedrooms on the first floor. The staircase is approximately in the middle of the house, which is expected to be an appropriate place for applying the wind catcher. Cooling is provided by air conditioners during the hot summers. The building has brick internal and external walls, and aluminium frame windows. External walls do not have any insulation. The windows are single-glazed and the floors are covered by concrete and ceramic tiles. It has a clay-tiled roof. The following Figures 1 & 2 show plans and sections of the building. Table 1 shows the existing materials used in the selected building.

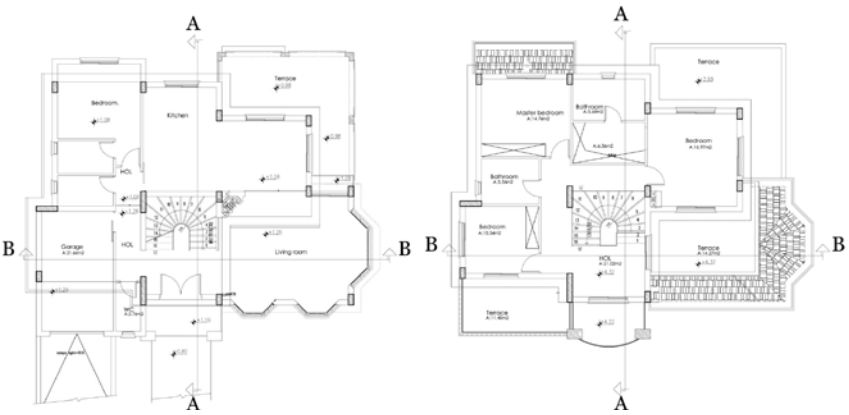

Figure 1*. Ground floor plan and first floor plan of the residential building in* Larnaca, *Cyprus*

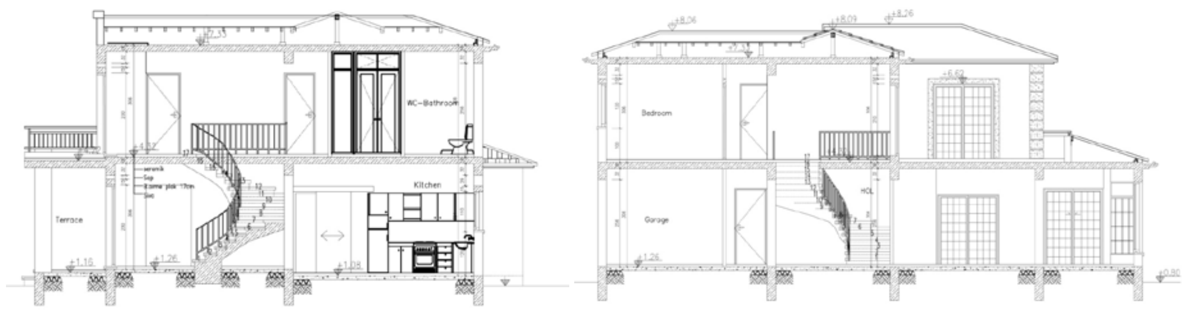

Figure 2*. Section A-A* *Section B-B*

Table 1. *Existing materials used in the case study building*

Walls: 110mm external brick plus, 75mm timber frame with 10mm plaster board inside U-Value (w/m^{2}k): 1.770
Floor: 100mm thick concrete slab on ground plus ceramic tiles U-Value (w/m^{2}k): 0.880
Windows: Single pane of glass with aluminium frame U-Value (w/m^{2}k): 6.000

Ceiling: 10mm suspended plasterboard ceiling plus 50mm insulation with remainder (150mm) joists as air gap U-Value (w/m^2k): 0.150	
Roof: Clay tiled roof U-Value (w/m^2k): 1.820	
Doors: 40mm thick hollow core plywood door U-Value (w/m^2k): 2.980	
Partition: 10mm framed wall as air gap with 10mm plasterboard in either side U-Value (w/m^2k): 2.200	

THERMAL SIMULATION AND RESULTS

The simulation aimed at analysing the thermal comfort within the building with the existing situation and materials. In Figure 3, an average of 19.5-29°C is the comfort zone limit in Cyprus, which is shown in white background. The red stands for hot (or overheating) and the blue stands for cold (or underheating). The results showed that the best thermal comfort is achieved in the months of April, May, October and November. These months needed no extra heating or cooling, but in the summer months (June, July and August) the use of cooling devices such as ceiling fans or air conditioners is essential. In Figure 4, each line considers one zone. As can be seen, on 13 August, which is the hottest day in Larnaca, the first floor is overheated.

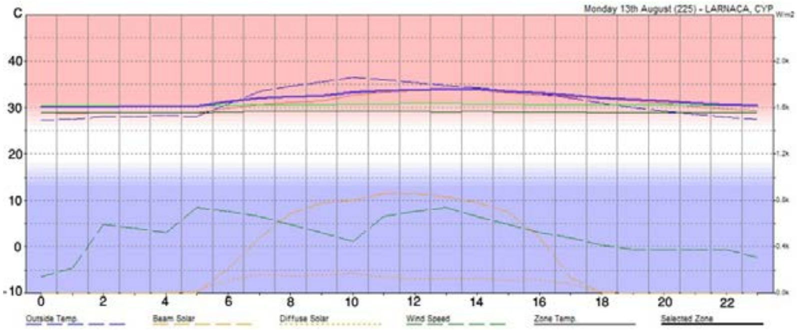

Figure 3. *Hourly temperature of ground floor plan*

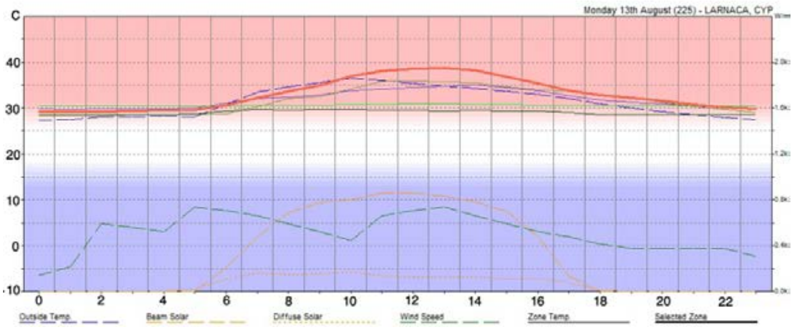

Figure 4. *Hourly temperature of first floor plan*

Both figures above show that the ground floor is above the thermal comfort limit during the day and the night. The difference between the outside and inside temperature is approximately 1 to 2°C. The first floor is also above the comfort zone limit during the day and the night. Further simulations have been carried out for the same building with existing materials but this time with the use of a wind catcher feature as shown in Figure 5 where it was applied over the staircase in the building. Since most of the bedrooms are on the first floor and all bedrooms are interactive spaces, the simulation were undertaken just for the first floor plan shown in Figure 6.

***Figure 5**. Section A-A* *Section B-B*

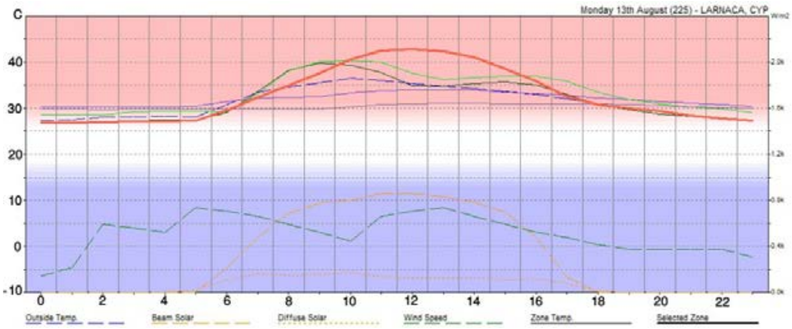

***Figure 6**. Hourly temperature of first floor plan after applying the wind catcher*

After applying the wind catcher, results have shown that, during the night, the temperature inside the first floor decreases by approximately 1 to 2°C; however, mostly at noon and between 10am and 2pm, the temperatures inside increased by approximately 4 to 6°C in comparison with the outside temperatures.

AIR FLOW ANALYSES AND RESULTS

Although the emphasis of the study was on thermal comfort in the building, since ventilation is very important in Cyprus, WinAir 4 programme has been used to analyse airflows as well as temperatures. In addition, an attempt was made to locate the wind catcher in front of the prevailing wind with four sides open, so that it can catch wind from all directions as well. Figure 7 illustrates the airflow in the building on 13th August as the hottest day. The prevailing wind in Larnaca is mostly from the south and south-west in summer. As can be also seen below, airflows are mostly through the cross windows as well as the wind catcher.

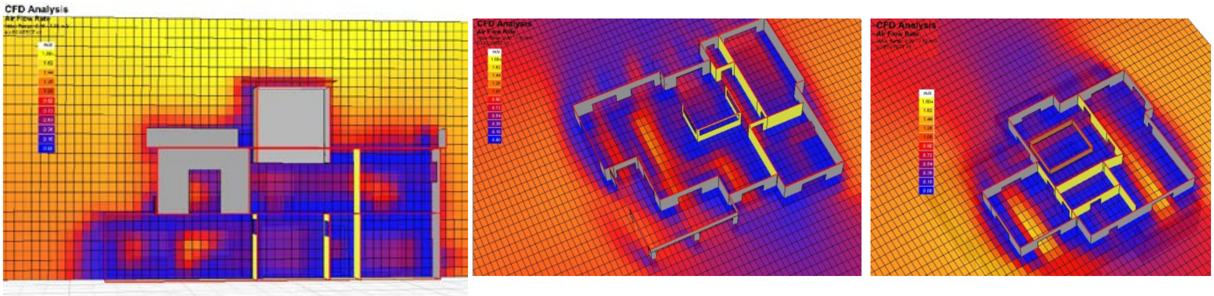

***Figure 7**. Airflow through the wind catcher and windows (XZ axis section); airflows in the ground and first floor*

Accordingly, the above figures demonstrate that ventilation in the building is provided mostly through cross windows and less through the wind catcher. It is obvious that rooms which are in the south are getting much more solar gain, and as a result, they are much warmer than other rooms. The temperature of each bedroom depends on the location of the space and climate, and the results for first floor showed average temperature.

FURTHER SIMULATIONS AND RESULTS

Further simulations have also been carried out with the same building and changed materials without applying the wind catcher. This was conducted on 13th August, the hottest day of the year according to the local weather data. The aim of this simulation is to discover how much reduction in the temperature of the building would be achieved by changing materials and improving in U-Values. An attempt has been made to use the current insulated materials in Cyprus with lower U-Values in the chosen building. Table 2 shows the applied materials in the case study building.

Table 2. *Applied materials in the case study building*

Walls: 110mm brick with 50mm cavity; 110mm concrete block with 10mm plaster inside and coir board on either side U-Value (w/m2k): 0.720
Floor: 100mm thick concrete slab on ground, plus timber finish U-Value (w/m2k): 0.430
Windows: Double glazed low-E with timber frame, with emissivity of 0.10 and 45mm air gap and 25mm argon gas U-Value (w/m2k): 1.820
Ceiling: 10mm suspended plasterboard with 75mm insulation and coir board on either side U-Value (w/m2k): 1.820
Roof: Clay tiled roof with aluminium foil, insulated with 50mm polystyrene foam U-Value (w/m2k): 0.150
Doors: 40mm thick solid core oak timber door, insulated with 75mm air gap, 25mm argon gas U-Value (w/m2k): 1.370
Partition: 75mm framed wall as air gap with 10mm plasterboard on either side U-Value (w/m2k): 2.250

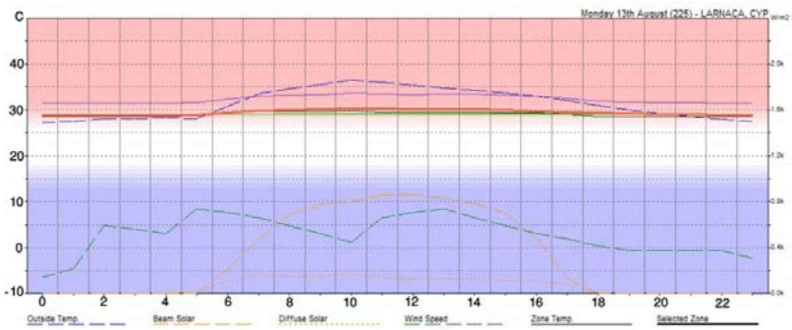

Figure 8. *Hourly temperature of the first floor plan after applying new materials*

In Figure 8, it can be seen that the temperature, from 6am in the morning to 8pm in the evening, decreases dramatically when the materials of the building are changed and some appropriate insulation is added. From 10am to 2pm, which is the hottest time in the day, the temperature is reduced by approximately 5 to 6°C. Despite the fact that there is a considerable decrease during the day, the difference between the outside and inside temperature during the night is almost 1°C. Below is the result of further simulations with the same materials as shown in Table 2 plus a wind catcher above the staircase in the selected building.

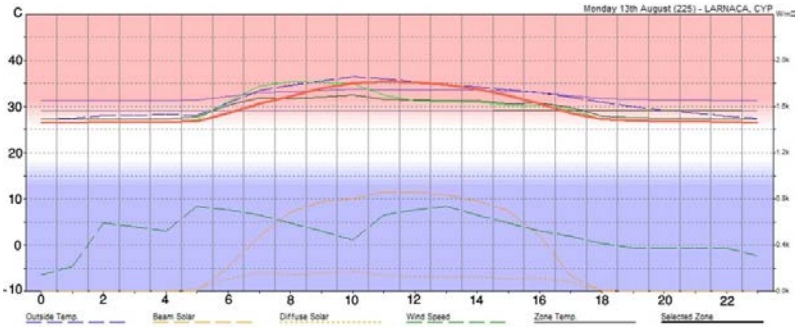

***Figure 9**. Hourly temperature of first floor plan after applying the wind catcher and insulation*

Figure 9 shows that, although between 8am in the morning and 4pm in the afternoon, the temperature of the building remains above the comfort zone; it decreases by approximately 2 to 3°C during the day and 1.5°C during the night. Therefore, in comparison with the outside temperature, the inside temperature decreases during the day and the night. In the building with wind catcher and modified materials, the temperature of the bedrooms remains in a comfort zone without using any air conditioner during nights which helps to reduce energy consumption in residential buildings in Larnaca.

CONCLUSION

Due to the hot and humid climate that Larnaca has, ventilation is really important during the summer. The prevailing wind on the other hand can be used as part of a passive cooling system in the region. Many contemporary houses in Cyprus are planned to use mechanical cooling systems that consume large amounts of energy. By using vernacular design, thermally efficient walls, low emissivity glazing, reduced openings on the south side and sufficient cross-ventilation through wind catchers and windows at nights, designers can make houses thermally comfortable in Cyprus. As residential buildings are among the major consumers of energy, it can be suggested that a traditional Middle Eastern wind catcher as well as insulating materials should be applied to the existing modern building in Larnaca to provide cool air for all or some parts of the building. Moreover, in comparison with the existing building and the building with a wind catcher, during the night the temperature in the building which is cooled by the wind catcher is comfortable, however during the day, especially at noon, the temperature inside increases by 3 to 4°C in contrast with the existing building. Again, in the building which includes insulated envelope the temperature decreases by approximately 8°C at noon in contrast with building with existing materials, which is really considerable.

The results of the study demonstrated that using appropriate materials which have lower U-Values is really essential for buildings in Cyprus. They reduce the temperature during the day and the night considerably, and as a result, lead to reduced energy consumption in the country. Using wind catchers is beneficial during the night when they lead to appropriate air flow and therefore to a reduction in indoor temperatures. During the day, even in a building without a wind catcher and with insulated envelope, using a mechanical cooling system just at noon and for some time in the afternoon is recommended. Although a wind catcher makes the inside warmer during the day, it can be used as a solar chimney. The side which faces the prevailing wind could be closed so that exhausted warm air could escape from upwind openings; this would provide appropriate ventilation during the day.

In conclusion, wind catchers are useful in Larnaca during the night to reduce energy consumption and increase the thermal comfort of occupants. Also, using appropriate insulation and local materials are essential to reduce the temperatures inside the building.

REFERENCES

Al-Shibami, F.H. 2002. *Thermal Comfort and Energy Efficiency in Yemeni Houses*, PhD Thesis, University of Sheffield, UK.

Chadha, C. 2010. *The Applicability and Thermal Performance of Downdraught Cooling in Residential Buildings in the main Climatic Zones in India*, MArch in Environmental Design, University of Nottingham, UK.

Dincyurek, O. and Turker, O. 2006. ‘Learning from traditional built environment of Cyprus: Re-interpretation of the Contextual Values’. *Building and Environment*, 42, pp. 3384-3392.

Dunster, B., Simmons, C. and Gilbert, B. 2008. *The Zed Book.* Abingdon, Oxon: Taylor & Francis.

ECOTECT, Autodesk web page. http://www.squ1.com/products/ECOTECT>. Accessed August 2011.

El–Shorbagy, A. 2010. ‘Design with Nature: Wind Catcher as a Paradigm of Natural Ventilation Device in Building’. *International Journal of Civil & Environmental Engineering IJCEE – IJENS,* **10**(3), 26-31.

Fathy, H. 1986. *Natural Energy and Vernacular Architecture.* Chicago: The University of Chicago Press.

Florides, G.A. et al. 2000. ‘Evolution of Domestic Dwellings in Cyprus and Energy Analysis’. *Renewable Energy,* 23, pp. 219-234.

Javid, A. 2007. *Modernizing the Traditional Ventilation of Yazd to Minimize the Energy Consumption for Hot Climate.* MArch in Advanced Architectural Studies, University of Sheffield, UK.

Lapithis, P.A. 2002. *Passive Solar Architecture in Cyprus*, PhD Thesis, University of Wales, UK.

Mahmoudi Zarandi, M. 2009. ‘Analysis on Iranian Wind Catcher and Its Effect on Natural Ventilation as a Solution Towards Sustainable Architecture’. *World Academy of Science, Engineering and Technology*, pp. 574-579.

Ozay, N. 2004. ‘A Comparative Study of Climatically Responsive House Design at Various Periods of Northern Cyprus Architecture’. *Building and Environment*, 40, pp. 841-852.

Pashardes, S. and Christofiedes, C. 1995.’ Statistical Analysis of Wind Speed and Direction in Cyprus’. *Solar Energy,* **55**(5), pp. 405-414.

Tabriz, M.B. 2011. *Vernacular Passive Cooling System in Existing Traditional and Modern Building*, MArch in Sustainable Architectural Studies, University of Sheffield, UK.