London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

Design Of An Advanced Cooling Tower For A Solar Decathlon House In Southern Europe

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INTRODUCTION

BACKGROUND AND CONTEXT

- The residential sector represents more than 25% of the entire energy consumption in the EU (Eurostat, 2013).
- In southern Europe energy demand for space cooling has an extremely relevant role.
- Colder countries, such as the UK, could experience a warming process over the next few decades (West and Gawith, 2005) and summer overheating in homes is already a problem (Beizaee et al., 2013).

THE RESEARCH HYPOTHESIS

Cooling towers are an important element of plus-energy houses in southern Europe.

AIM

To identify and test refinements to the design of the existing ventilation tower of a plus-energy house.

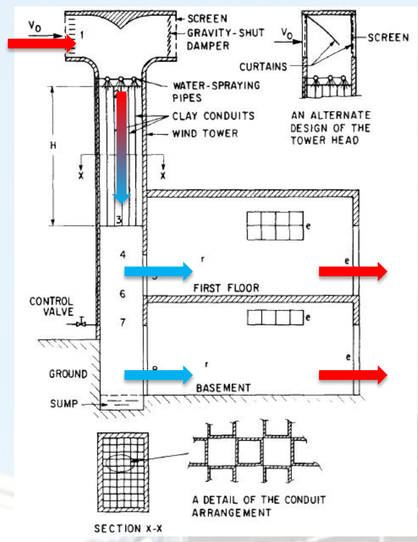
PREVIOUS WORK: 1985 --> 2014

PLUS-ENERGY HOUSE

A residential building whose annual energy balance is positive (Disch, 2009).

VENTILATION COOLING TOWER

A system based on ancient wind towers . It can provide a living space with fresh and cool air in warm and dry countries.



(Bahadori, 1985)

MODELLING TECHNIQUES

Both dynamic thermal modelling and computational fluid dynamics are essential.

THE GAP

Very little was known about the role of these systems within a plus-energy house.

CONCLUSIONS

KEY FINDINGS

- Energy demand for space cooling can be halved
- Tower performance are more predictable relying on buoyancy
- Internal thermal comfort is still guaranteed

Winning presentation at MC2014, London

A ventilation cooling tower is a possible low energy solution in plus-energy houses.

THE "HOME+"

The “Home+” is a plus-energy home designed at the Hochscule für Technik Stuttgart in Germany.

It won the 3rd prize at the 2010 Solar Decathlon Europe Competition in Madrid.

Its ventilation tower, which relies on wind as driving force, did not perform as expected.

RESULTS

ENERGY SAVINGS

The implementation of the tower within the “Home+” can halve the annual energy demand for space cooling.

[kWh]	Athens	Cordoba	Sevilla	Zaragoza	Thessaloniki	Evora	Catania	Foggia
Without	4430	4257	4903	2563	3347	2818	3139	2700
With	2740	2253	3196	1239	2072	1483	1728	1467
Difference	1691	2004	1707	1324	1275	1335	1411	1233

PDEC WATER CONSUMPTION

Both mean and peak water consumption figures reach their maximum at Cordoba, namely 7.7 and 14.4 l/h respectively, as well as the number of hours of operation, 1499.

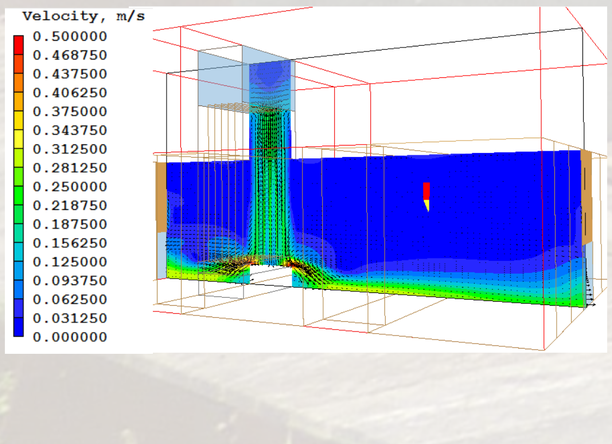
CO_2 AND MOISTURE CONTENT

- Best practice CO_2 threshold, 900 ppm (CIBSE, 2006), is never exceeded, being 833 ppm the highest peak value.
- According to the chosen control strategy, the PDEC system does not operate when the moisture content within the house exceeds 15 g/kg . Mean levels are comprised between 8.41 g/kg, at Zaragoza, and 10.13 g/kg, at Catania.

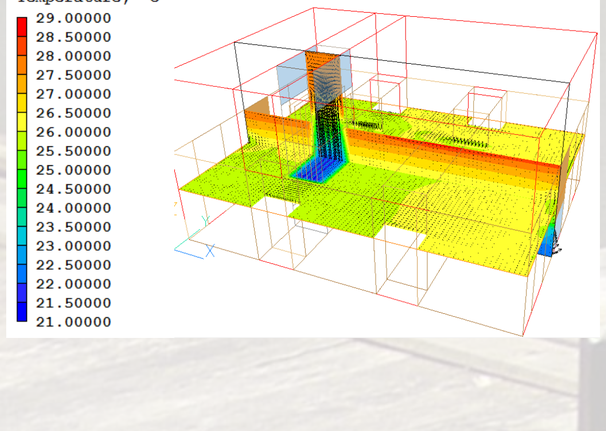
AIR CHANGES PER HOUR

Values hypothesised in dynamic thermal modelling, 6.3 h^{-1}, and estimated with computational fluid dynamics modelling, 5.6 – 6.9 h^{-1}, are extremely close.

VELOCITIES DISTRIBUTION



TEMPERATURES DISTRIBUTION



METHODS

THE LOCATIONS

The choice was based on:

- Wet bulb depression, wet bulb temperature
- Comfort criteria: temperature between 20°C and 27°C and absolute humidity between 4 g/kg and 15 g/kg
- Availability of weather data

IMPLEMENTATION, TEST AND ANALYSIS OF REFINEMENTS

<u>Dynamic thermal modelling</u>

- mean and peak CO_2 levels
- temperature
- energy consumption
- the boundary conditions for the CFD model
- PDEC water consumption

❖ PDEC → “post-processing” method (Robinson et al., 2004)

❖ 2 simulations per location

<u>Computational fluid dynamics modelling</u>

- fresh air distribution
- indoor air quality
- ventilation rates
- cooling potential

❖ one location

❖ one instant

❖ four building configurations