The Passivhaus standard in Southern Europe

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ABSTRACT

More than 8.000 homes have been built to the *Passivhaus* standard in central Europe. The success of *Passivhaus* is due in large measure to it being a well defined product, understood by the developer, architect and future owner. However the *Passivhaus* standard was born to respond to the requirements of a relatively cold region. The EIE funded Passive-On project has examined what elements of the standard could be useful in promoting the diffusion of low energy house design in southern Europe. On the one hand numeric modelling has shown that in Italy and the South of France the solutions utilised in the central European *Passivhaus*, can with suitable modification, provide an effective basis for providing cool homes in summer. However on the other hand though the solutions may work, the implicit and explicit requirements of the *Passivhaus* standard can nevertheless represent over engineering in warmer climates. For example the *Passivhaus* standard makes an explicit requirement to limit the permeability of the building envelope ($n_{50} < 0.6\ h^{-1}$) which makes an implicit need for active ventilation. However experience, for example from Spain and Portugal, shows that effective low energy homes can be built without the need for ventilation systems. The paper discusses the results of the numeric modelling showing how, with suitable adaptation, the passive design applied in the central European *Passivhaus* can be effective in providing comfortable homes in Nice, Carpentras, Milan, Rome and Palermo. The paper also presents changes proposed to the current *Passivhaus* standard to allow designers in the southern Europe to employ alternative passive designs whilst ensuring that these provide guaranteed results in terms of energy and indoor comfort.

1. INTRODUCTION

In 1991 Wolfgang Feist and Bo Adamson applied passive design to a house in Darmstadt, with the objective of providing a show case low energy home at reasonable cost for the German climate. The design proved successful both in terms of energy consumption and comfort such that the same passive systems were applied again in a second construction in 1995 in Groß-Umstadt. By 1995, based on the experience from the first developments, Feist had codified the Passive Design of the Darmstadt and Groß-Umstadt homes into the *Passivhaus* standard.

In total more than 8.000 houses have now been built in Germany and elsewhere in central Europe (for example Austria, Belgium, Switzerland, Sweden) which conform to the *Passivhaus* standard.

Compared to the total annual development of new homes in Member States, which in many cases run into several hundred thousand a year, these figures may seem insignificant. However compared to other attempts at developing low energy homes over the last thirty years in Europe, the results seem quite exceptional.

It is thus reasonable to ask what if any elements of the *Passivhaus* standard born in response to the requirements of cold central Europe are pertinent or can be adapted to the requirements of homes in relatively warm southern Europe where the need to provide comfort in summer often predominates over the need to maintain homes warm in winter.

The EU EIE funded Passive-On project, (Contract no. EIE/04/91) examined the issue and sought to answer two questions:

i) Can the basic premise of the *Passivhaus* as built in central Europe , but with suitable modification provide for low energy comfortable homes in a Mediterranean climate ?

ii) How can the current *Passivhaus* standard be modified to more adequately reflect the needs of southern Europe?

2. A *PASSIVHAUS* FOR FRANCE AND ITALY

2.1 Premise and proposal

The central European *Passivhaus* adopts four main strategies to control energy flows and guarantee winter comfort, namely: high envelope insulation, lack of thermal bridges, air tight envelope and active ventilation with heat recovery.

Considered in respect of southern Europe these solutions are:

- pertinent to many areas of the South of France and Italy with relatively cold if short winters for example Northern Italy, but also mountainous regions further south

− potentially when integrated with additional solutions, provide the basis for passive cooling.

Regarding the last issue, a well insulated heavy structure provides an effective basis for utilising the low enthalpy of night time air to cool the building structure. Night time air can be passed through the building either by operating a purely natural ventilation strategy, or by using the the ventilation system common to standard *Passivhaus* design.

The high envelope insulation likewise provides an effective means in summer to reduce heat gain and the heat exchanger can be used to lower the enthalpy of incoming air by increasing the enthalpy of vented air

However additional solutions would also likely be required:

− window shading to reduce solar gain

− a reversible heat pump to provide for limited active cooling should the night time ventilation strategy prove insufficient.

2.2 Methodology

To test the premise computational models were developed of homes implementing the passive heating and cooling strategies listed in the previous section. A model of the French house was developed by the *Passivhaus Institut* using the Dynbil energy simulation software and a model of the Italian house was developed by eERG using US DOE energy-plus. Both groups considered an end of terrace of 120 m^2 with floor plans and space distribution typical for the regions.

2.2.1 Climate

For France the model was tested using climatic data for Carpentras and Nice. Compared to Northern France, the Carpentras climate is mild and sunny. The lowest temperature in the data set is –5 ° In winter, the daily average temperature hardly drops below 0 ° and there is an amount of solar radiation available for passive solar heating. The highest ambient temperature is 35 ° C, but daily average temperatures in summer do not exceed 25 ° C. This means a considerable potential for cooling by means of night ventilation.

In Italy, Milan, Rome and Palermo were considered. Rome provides probably the most favourable conditions with mild winters (average minimum 5°C) and a relatively large diurnal temperature swing in summer (on average 10°C), providing potential night time ventilation. Though winters in Palermo are mild, summers are hot with very low diurnal variation (on average 3°C), making effective night time ventilation of the building mass difficult. Of the three Milan represents something of a worst case scenario with cold winters (minimum -9) and hot humid summers (maximum 34°C). However on the positive side, average diurnal temperature variations are reasonably high (8°C).

2.2.2 Objectives

The *Passivhaus* standard as defined for central and north Europe makes a 15 kWh/m^2/year limit on heat demand. In moving south decreases in heating load would be offset by an increase in cooling loads. In the first instance the group made the assumption that this offset would be proportional and decided upon a 15 kWh/m^2/year combined limit for both heating and cooling demand. The simulations themselves would indicate whether this target was reasonable.

It has little meaning to speak of household energy consumption if this is not connected in some way to indoor comfort conditions. For what regards winter, an indoor operating temperature of 20°C was sought.

For what regards summer, the partners employed the algorithm based on the Adaptive Comfort model defined in the EN 15251 standard. In the summer the algorithm defines the daily indoor comfort temperature ($T_{comfort}$) as a function of past daily temperatures (running mean temperature: T_{rm}) using the following algorithm (1):

$$(T_{comfort})_d = 0.33 \cdot (T_{rm})_d + 18.8$$

$$(T_{rm})_0 = (1-\alpha) \cdot \left\{(T_o)_{d-1} + \alpha (T_o)_{d-2} + \ldots + \alpha^5 (T_o)_{d-6}\right\}$$

$$(T_{rm})_d = (1-\alpha) \cdot (T_o)_{d-1} + \alpha \cdot (T_{rm})_{d-1}$$

T_{rm} is calculated using the mean outdoor temperature (T_o) of the last previous six days together with the time constant α (=0.8).

Importantly, according to the model, comfort conditions are independent of the relative humidity.

The choice to use the Adaptive Model was discussed widely by the project consortium. Most current building regulations, the definition of thermal comfort follows the ISO 7730 standard which is based on the steady-state Fanger model. However in recent years, some international standards (e.g. the US norm ASHRAE 55 2004 and the European norm EN 15251) have proposed Adaptive comfort models based on in-field comfort surveys. Using the Adaptive model to asses building comfort performance allows building design to move closer to real-life comfort requirements and at the same time to reduce cooling energy demand.

Using the hourly climatic data available for the five test localities it was possible to determine the indoor comfort temperature as defined by (1) and compare this with the indoor operating temperatures as predicted by the simulations.

2.3 Results

Though the *Passivhaus* for Italy and South of France adopt many of the passive concepts of the German *Passivhaus*, specific details do change. Generally the milder climate of Italy and South of France allows the *Passivhaus* standard energy limits and comfort conditions to be achieved using less stringent criteria in relation to:

− insulation levels: A typical German *Passivhaus* will require 25 cm of insulation on external walls and 40 cm on the roof. However in Rome 10 cm wall insulation and 15 cm roof insulation proves sufficient.

− envelope air tightness: The central European *Passivhaus* requires that building envelopes provide at maximum 0.6 h^{-1} air change rate at 50 Pa pressure difference ($n_{50} < 0.6$ h^{-1}). However in Italy and South of France a n_{50} value of a 1 h^{-1} should prove acceptable.

The important difference however is that the *Passivhaus* in the South of France and Italy uses night flushing of the building mass combined with, if necessary, low powered active cooling in the daytime to provide summer comfort conditions.

The work conducted by eERG showed that night ventilation strategy reduces cooling demand from 20% in Palermo to 80% in Milan. Without night flushing the high envelope insulation risks increasing cooling loads by trapping gains in the house.

Figure 1 shows the heating and cooling energy demand for the three localities in Italy whilst Figure 3 compares the average indoor operating temperature in summer with the comfort temperature as predicted by the Adaptive model for Milan.

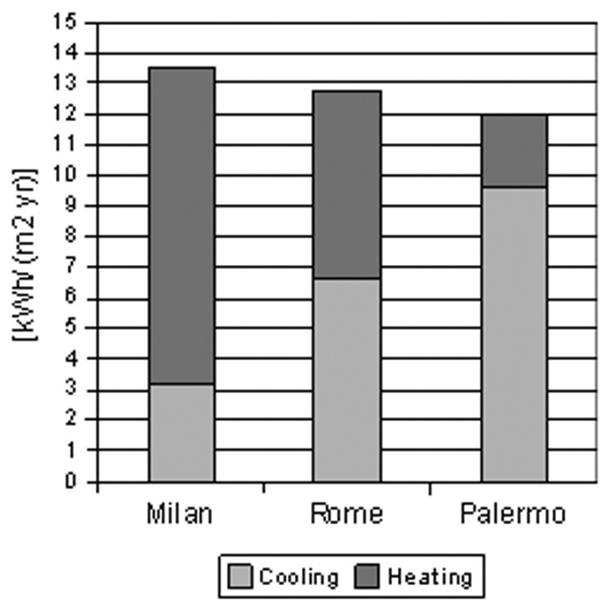

Figure 1. Heating and cooling demand of the Italian Passivhaus

The *Passivhaus Institut* found that night ventilation strategy was effective in Carpentras and no active cooling was required (cooling loads were therefore zero). However Nice has a more humid climate and though night ventilation can be useful, dehumidification might be required for optimum comfort. As a consequence cooling loads are higher than those predicted by eERG for Italy, (Figure 2).

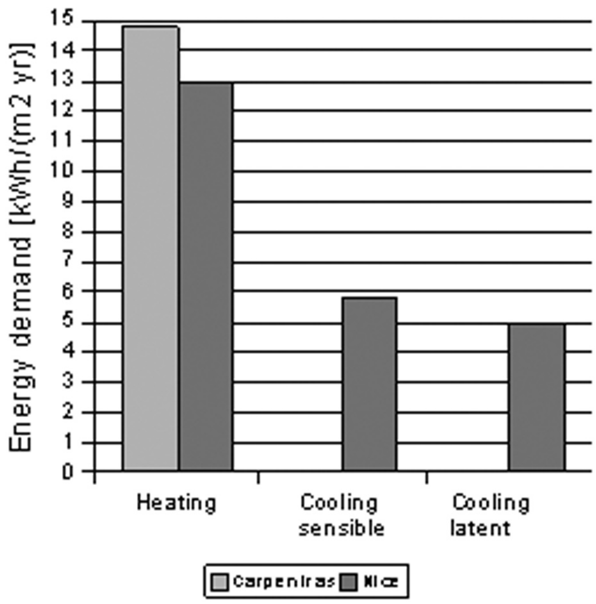

Figure 2. Heating and cooling demand of the French Passivhaus.

2.4 Conclusions

Generally the initial premise proved founded and the simulations have provided relatively consistent results in terms of energy consumption and space comfort though there are some differences between the work conducted by the *Passivhaus Instiut* and eERG.

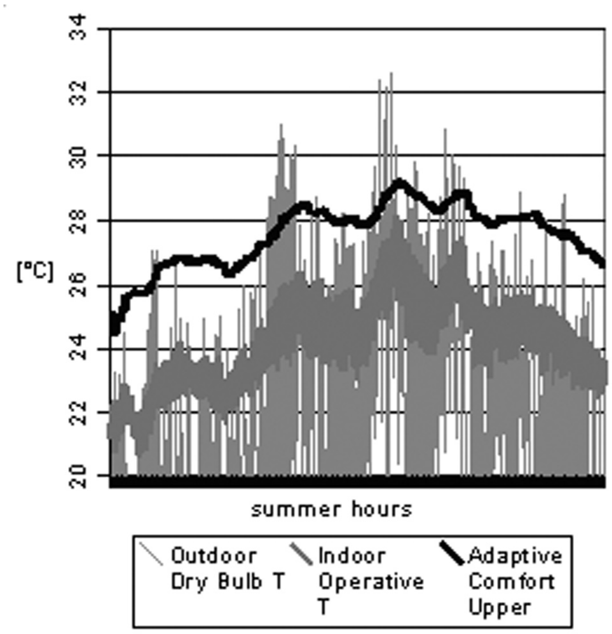

Figure 3. Indoor compared to EN 15251 predicted comfort temperatures for the Passivhaus in Milan

Importantly eERG worked to the Adaptive model which links comfort entirely to temperature and not to humidity. As a consequence the simulations only considered sensible cooling loads which were relatively low such

that total cooling and heating loads respected the 15 kWh/m^2/year limit.
In Carpentras, the *Passivhaus Institut* found that night time flushing was sufficient to provide comfortable indoor daytime conditions. Thus cooling loads are zero and again total energy demand respects the combined 15 kWh/m^2/year limit as set out in Section 2.2.1. However in Nice, the *Passivhaus Institut* also considered dehumidifying. Total cooling loads (sensible and latent) are therefore high and it no longer proves possible to meet the 15 kWh/m^2/year combined limit.
Though we are not suggesting that the proposed design represents the best passive design for southern Europe we hope to have shown that with suitable modification the *Passivhaus* design set will, if required function in warmer climates whilst respecting the required energy limit. The advantage to our mind of developing a low energy home for Italy or the South of France based on the concepts applied in the central European *Passivhaus* are that these can be readily integrated in homes with commonly accepted aesthetics and layout. For example the active ventilation system can be used in summer to provide night time ventilation without the need for special (and maybe to some aesthetically displeasing) stacks or without specific attention to space distribution (though certainly this could help).

3. A *PASSIVHAUS* STANDARD FOR WARM CLIMATES

In total more than 8.000 houses have been built in Germany and elsewhere in central Europe which conform to the *Passivhaus* standard. What makes the *Passivhaus* concept so successful is that the *Passivhaus is a well defined product,* understood by the developer, architect and future owner.
This would indicate that a standard for southern Europe would also be advantageous. In addition as incentive programmes and obligations become more common then what we mean by Passive House and what we aim to promote and disseminate actually becomes a necessity. For example how should Member States respond to the wish expressed in the EU Commission "Action Plan for Energy Efficiency" approved in 2006 for more wide spread development of Passive Houses by 2015 ?
The *Passivhaus* standard is a successful standard but was born to respond to the requirements of relatively cold central Europe.
Certainly on the one hand the analysis as described in Section 2 has shown that, in southern regions the solutions utilised in the standard *Passivhaus,* can with suitable modification, provide an effective basis for providing cool homes in summer.
However on the other, the implicit and explicit requirements of the *Passivhaus* standard can represent over engineering in southern Europe. For example the *Passivhaus* standard makes an explicit requirement to limit the permeability of the building envelope (n50 ≤ 0,6 h-1) which makes an implicit need for an active air ventilation system. However experience, for example from Spain and Portugal, shows that effective low energy homes can be built without the need for active ventilation systems and with less stringent building shell criteria. The Passive-On consortium has therefore proposed a number of changes to the current *Passivhaus* standard to make it relevant to warmer climates. The aim is to allow designers in the Mediterranean to adopt Passive Design appropriate to the region whilst ensuring that these provide guaranteed results in terms of energy and indoor quality. The full proposed revised definition of the *Passivhaus* standard can be viewed at www.passive-on.org However the principle changes aimed to make the *Passivhaus* standard relevant to the Mediterranean are:

- the introduction of an explicit limit for summer cooling energy demand (15 kWh/m^2 year);
- minimum requirements for summer comfort; indoor summer temperatures are not to exceed the Adaptive Comfort temperature as defined in the EN 15251 standard. Using the Adaptive Comfort model ensures comfortable temperatures compatible with Passive Design;
- relaxing the limit on the air tightness of the building envelope to $n_{50} \leq 1$ h-1

The use of the German term *Passivhaus* for a standard pertinent to the Mediterranean has been the source of much discussion. On the one hand there is a risk that the concept be interpreted incorrectly as an attempt to export the German prescriptive solutions. However the alternative of using national language translations was found unpopular. In particular not all professionals, some of them involved in Passive Design for many years, particularly liked the idea that the generic word Passive be associated with a specific construction standard. They wanted and want the freedom to apply the term Passive Home to any Passive Design, irrespective of whether this home meets the requirements set out in the *Passivhaus* standard.
Thus to avoid confusion the choice was made to use *Passivhaus* in relation to those homes which meet the revised *Passivhaus* standard and the term Passive House or its translation in national languages to refer to homes which integrate some general form of Passive Design (and which may or may not conform to the standard).

REFERENCES

EN 15251 Standard (2007). Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics.
Action Plan For Energy Efficiency (2006). Releasing the Potential.