PASSIVHAUS AND PHPP – DO CONTINENTAL DESIGN CRITERIA WORK IN A UK CLIMATIC CONTEXT?

Robert S. McLeod [1], Christina J. Hopfe [2], and Yacine Rezgui [2]
[1] Cardiff University, School of Engineering, Cardiff, and BRE Wales and SW
[2] Cardiff University, School of Engineering, Cardiff, Wales UK

ABSTRACT

The Welsh Assembly Government has implemented an 'aspirational' target that from 2011 all new buildings in Wales must be 'zero carbon,' five years ahead of the 2016 deadline originally set for homes in England. The PassivHaus concept developed in Germany has grown steadily in Europe demonstrating a reliable methodology for the design of ultra low energy buildings, therefore providing the possibility of an established method of meeting the zero carbon targets in Wales.

Social housing projects currently being designed in Wales and Ireland using the PassivHaus Planning Package (PHPP) have highlighted challenges that may have strong implications for the design of future 'zero carbon' dwellings in the UK and Irish maritime climates.

This paper will discuss the above in more detail by showing the implications of applying the PassivHaus standard in Wales and examining the standard for its appropriateness in the supposedly milder Welsh climate. The research conducted will demonstrate that the PassivHaus concept offers a useful template but that it also implies uncertainty due to its thermal performance in the middle European maritime climatic zones with corresponding implications for design sensitivity.

INTRODUCTION

The need to limit CO_2 emissions resulting from the construction and operation of the built environment is well established (Boardman et al, 2005). In support of overarching European emission targets the European Parliament's Industry Committee declared, that by 2019 the 'Zero Net Energy' target must be achieved i.e., all newly constructed buildings must produce as much energy as they consume on-site (ECEEE, 2009).

Against this backdrop, the Welsh Assembly Government (WAG) has set its own ambitious target that all new buildings should be 'zero carbon' by 2011(Jones, 2007). This is five years ahead of the 2016 deadline set for England by the UK Government (Weaver, 2006) (HM Treasury, 2006). These targets will require huge changes to current design and construction practices impinging on all sectors of the industry; including material component manufacture, on-site operations and all aspects of their operations, skills, financing and transport (NHBC, 2008).

The purpose of this short paper is to examine the impact of adopting the PassivHaus standard in a UK maritime design climate that differs significantly from that of continental Europe where the PassivHaus standard originated.

The German Passivhaus standard appears to be a well established route to achieve the UK's zero carbon targets, although it is not zero carbon in its own right as it still requires some heating and power for ventilation, (unless these can be supplied by a zero carbon means), and so could provide a useful starting point for developing zero carbon buildings.

This paper will investigate its possible role in the delivery of zero carbon housing to meet the 2011 target for Wales.

The paper begins by describing the background to the aspiration set out by WAG. This is followed by a brief description of the Passivhaus standard before describing some research carried out on the first prototype social Passivhaus dwellings in Wales. The results of the research are discussed before widening the scope of the discussion to consider how the Passivhaus standards might be more robustly adapted to the Welsh context. The paper concludes by identifying the main technical issues that face the implementation of the PassivHaus standard as a template for low and zero carbon housing in the UK.

BACKGROUND

PHPP and the *Passivhaus* standard

Dr Wolfgang Feist founded the Passivhaus Institut (PHI) in Germany to oversee the development and certification of this concept and to act as the guarantor for the strict criteria and requirements for Passivhaus certification.

Arguably from an operational perspective the most important of these requirements is that the peak space heating load does not exceed 10W/m^2 so that a comfortable indoor climate can be maintained without using a conventional heating system in a central European climate (Schnieders and Hermelink, 2006). Secondly, and most often quoted in relation to the Passivhaus standard, namely that the specific annual heat requirement must not exceed 15kWh/m2 per annum. Additional criteria include an air tightness standard not exceeding 0.6 ach-1 and a Primary Energy Demand not exceeding 120kWh/m2.yr which must also be met in order to obtain Passivhaus certification (Feist, 2007).

In practical terms, the ultra low heating demand in a Passivhaus makes it feasible to do away with a conventional heating system completely and use low energy alternatives, such as post-heated supply air to supplement the 'free' heat gains provided by the sun, the building's occupants and appliances. A variety of supplementary heating systems have been successfully used in Passivhaus buildings, including electrical and solar hot water powered post-air heating, compact services units and district heating.

As a result of focusing on reducing space heating demand the Passivhaus standard is defined by an energy performance specification rather than a CO2 emissions rating (as used by the UK Building Regulations). Unfortunately, for the current study, this energy-based approach in Passivhaus creates a risk of there being significant variability in the actual CO2 emissions depending on the fuel used in the heating system. For this reason the Association for Environment Conscious Building (AECB), one of the early adopters of the Passivhaus standards in the UK, has imposed an additional carbon limit on the Passivhaus projects they certify (AECB, 2008)
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In summary, the Passivhaus concept is characterised by the use of a highly insulated thermal envelope, incorporating construction detailing that virtually eliminates thermal bridging. This is combined with a highly efficient Mechanical Ventilation with Heat Recovery (MVHR) system which operates at relatively low flow rates, providing continuous ventilation rates in the region of 0.2-0.4 ach^{-1} during the heating season. Dwellings are orientated to maximise passive solar gains in winter where possible, however this is not seen as a prerequisite of Passivhaus design and the standard has been demonstrated in a number of northern European urban contexts where south facing solar orientation was not feasible due to site constraints (Feist et al, 2005) (Schnieders and Hermelink, 2006) .

With nearly twenty years of research and development in Central Europe the Passivhaus standard represents an established method of delivering very low energy buildings.

One of the key tasks of current projects in the UK has been to assess the suitability of adopting the Passivhaus standard as a template for the widespread economic role out of low and zero carbon housing.

However, the problems in adapting this template due to the maritime climate conditions in the UK and Ireland, which differ significantly from the typical European continental climate, are obvious. This study seeks to investigate any important climatic influences on the implementation of the Passivhaus standard in these regions.

Applying PassivHaus standards in Wales

Earlier research in to Passivhaus design hypothesised that because the climate in the UK and Wales is milder than that of central Europe, it may be slightly easier to meet the Passivhaus standard (Schneiders, 2003) (Tweed and McLeod, 2008); thereby allowing the construction a degree of tolerance in its adaptation to the UK context.

The ability to reduce the peak supplementary heating load to 10W/m^2 or less is a key characteristic of the Passivhaus concept; since reducing the peak load to this level allows a small ventilation supply air post heater to meet the entire specific heat requirement. In terms of applying the Passivhaus standard to the Welsh context this raises a fundamental question: The Post Heated Supply Air maximum load (PHSA) is a product of the rate of supply air changes (V) the maximum winter design temperature difference ($\Delta\theta$) and the volumetric specific heat capacity of air (ρ.cp)

$$PHSA = V.\ \Delta\theta.\ \rho.cp$$

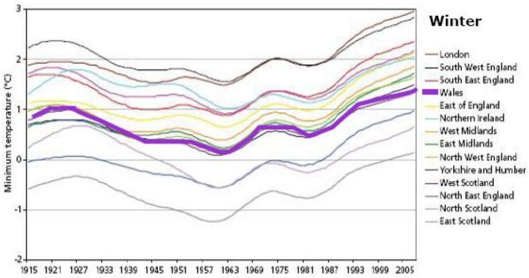
Inserting typical values for the rate of ventilation air change, the central European climate, and the properties of the air results in (after Brans, 2008):

$$\begin{aligned} PHSA &= 1m3/(hm\text{-}2).\ 30K.\ 0.33Wh/(m3K) \\ &= 10\ W/m2 \end{aligned}$$

The relatively low upper limit to the peak heating load of 10W/m^2 is therefore a consequence of these three boundary conditions. The upper limit of the temperature that the supply air can be raised by (ΔT) is limited by the 'toasting' phenomena of dust circa particles on the post heating coil which is reported to occur at circa 52°C (Feist et al, 2005). .

Whilst external design temperatures of -10˚C exist in central and northern continental Europe, winter daily minimum temperatures for Wales have (on average) exceeded 1˚C over the past 50 years (UKCIP08, 2008). For the past decade average winter minimum temperatures have been consistently above 2˚C across Wales (UKCIP08, 2008). Global air temperature records also illustrate a pronounced upward trend towards warmer than average design years reflecting both increasing minimum design temperature's and a reduction in the absolute number of heating degree days.

Figure 1.UK Minimum daily mean temperatures in winter since 1915 (UKCIP08, 2008)



Despite climate data for Wales suggesting a more appropriate winter design temperature in the region of 2˚C as opposed to -10˚C it must be acknowledged that these figures do not illustrate the most extreme design temperatures possible, nor do they show sub-regional temperature variations, irradiation or wind exposure implications. Even accounting for regional variations in the minimum winter design temperature, it is likely that a slight relaxing of some aspects of the Passivhaus performance standard as applied in Wales is appropriate where peak loads well within the 10W/m2 requirement can be demonstrated (Schneiders, 2003)

Satisfying the PassivHaus standard in different climatic zones across Europe

Research on UK Passivhaus heating load sizing was carried out by Schneiders under a European funded PEP project in 2003. Schneiders' parametric study illustrated that with an end of terrace dwelling and with opaque U values of 0.17 W/(m^2K) and glazed U values of 0.85 W/(m^2K) it is possible to comfortably meet the Passivhaus heating load and peak demand criteria using the Manchester climate provided that a south facing glazed area of between 10 and 30 m2 is used in the reference dwelling. This glazing range can be considered reasonable since the reference dwelling used in the study is based upon an end of terrace dwelling with an exterior façade area of 74m2, total glazed area of 30.4m^2 and a south facing glazed area of 19.9m^2 (Schneiders, 2003) .

The derivation methodology for the heating load sizing assessment in PHPP07 is based upon the use of two different extreme weather data sets Weather 1 (W1) and Weather 2 (W2). These two data sets consist of directional radiation occurring during cold clear (W1) conditions and cloudy (W2) conditions (Feist, 2007). The datasets in PHPP07 where derived form Test Reference Years (TRYs) and reflect conditions which are likely to occur once every two years, to which an additional safety margin of approximately 1.5 W/m2 is added (Schneiders, 2003).

The use of MeteoNorm software allows another approach to generating this peak load irradiation data by allowing the interpolation of site specific extreme 10 year periods for the purpose of sizing peak loads. In theory this method should provide more robust data, although there is uncertainty with micro climatic influences when interpolations are carried out from measured data that is taken some distance from the site (Oberrauch, 2008).

Schneiders' research illustrates that there is a clear correlation between increased glazing area and increased peak heating loads, as might be anticipated. However in more temperate climates such as Amsterdam, Birr (Ireland) and Manchester an inverse correlation also exists between annual space heating demand and glazing area. This finding has also been demonstrated in colder climates where more advanced glazing standards were specified (Schneiders, 2003). It is clear from this research that an optimum relationship between heating load, heating demand and glazing area needs to be determined on a location specific and glazing dependent basis for each Passivhaus project.

Further research investigating the effect on peak heating loads and space heating demand of slightly relaxing Passivhaus thermal standards has also been carried out by researchers at Lund University, Sweden. Thermal modelling carried out on an apartment building at Värnamo, Sweden demonstrated that the difference between using windows with an installed U-value of 1.0 W/m2K instead of the PHI recommended installed value of 0.85 W/m2K resulted in only a small increase in the peak heating load from approximately 8.8 W/m2 to 9.8 W/m2 while the annual space heating demand remained well within PHI criteria (Janson and Wall, 2007). Considering that the winter design temperatures in this study (Värnamo, Southern Sweden, with monthly low averages in January and February of approximately -6˚C) are significantly colder than in Wales, this finding has particular relevance to the adaptation of the Passivhaus thermal performance criteria to the Welsh context.

CASE STUDY

The case chosen is Hywlus Haus a 3bdm (87m^2) detached Passivhaus project in Ebbw Vale, Wales. This is one of the first social Passivhaus projects in Wales and is due for completion in July 2010.
Ebbw Vale is situated in a location where the affects of a maritime proximity combined with a mountain valley situation dominate the climate. This situation is common to many of the old mining towns situated

in the 'Valleys' region north of Cardiff. Much of this area suffers from severe social and economic deprivation and is receiving significant regeneration funding from the Welsh Assembly Government (WAG). As a result this area has become a focal point for the construction of social housing in the Passivhaus format.

Consideration of the annual (space heating) energy demand and peak load are of considerable importance in the design of Passivhaus dwellings particularly where post air heating is used as the primary source of supplementary heat input.

Results

In the absence of PHPP or Test Reference Year data for the Ebbw Vale site a bespoke climate data set was generated for this location using the MeteoNorm (MN) software (version 6). The methodology and limitations of this approach with respect to generating climate data for use in conjunction with PHPP are reasonably well documented (Oberauch, 2008). The unique feature of MeteoNorm is that it is able to interpolate between measured data sets to generate data for almost any given location. As with any software the outputs are a function of the source data and for this reason MeteoNorm requires a degree of judgement in the interpretation of the results.

The outputs for the annual heating energy prediction and peak load calculation can be compared for Hwylus Haus in Ebbw Vale by using the PHPP07 default data set for Manchester and the MeteoNorm data generated specifically for the site (Figure 2).

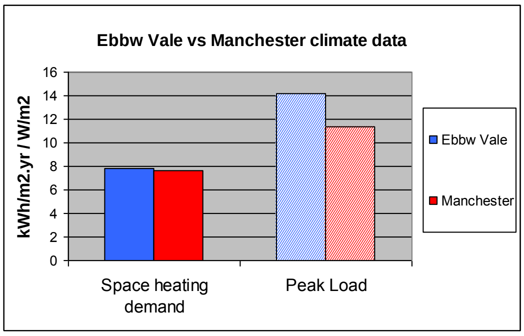


Figure2. Heating and Peak Load using Manchester (PHPP) and Ebbw Vale (MN)

Despite Manchester being further north than Ebbw Vale and therefore theoretically receiving less annual irradiation (fig3) the PHPP07 results show a slightly higher space heating demand and a significantly increased peak load requirement for the dwelling if constructed in Ebbw Vale.

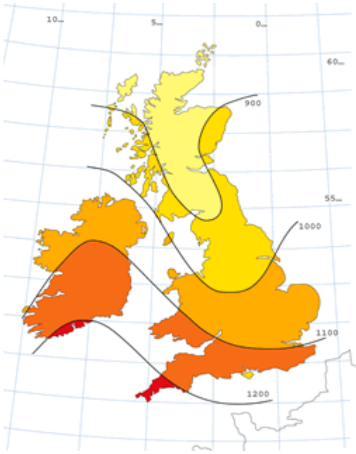


Figure 3. Irradiation map UK(ref)

During overcast conditions in winter (W2) radiation levels are significantly lower than during cold clear anticyclonic conditions (W1) and this results in the peak load often occurring after prolonged periods of cloudy weather despite the typically milder ambient temperatures during this time.

Comparing the W1 and W2 data for Manchester and Ebbw Vale illustrates the reason for the differences in peak loads. Interpolated data shows that Ebbw Vale receives far less incident irradiance during the critical winter peak load period than Manchester, despite average irradiation levels across the year being somewhat higher in Ebbw Vale as might be anticipated by the more southerly location.

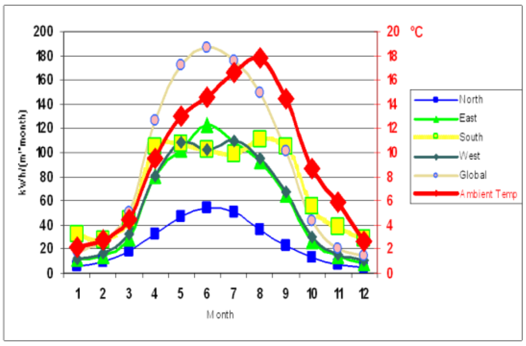


Figure 4a Monthly irradiance - Ebbw Vale

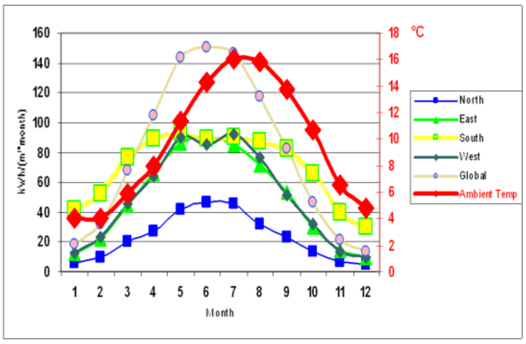


Figure 4b Monthly irradiance – Manchester

Most significant differences between the two Peak load predictions occur as a result of the differences between predictions occurring under the influence of the prolonged cold cloudy weather (W2) which dominates during the heating season in Ebbw Vale.

DISCUSSION

The findings of this study broadly confirm that the Passivhaus standard can be more easily achieved in a Welsh climatic context than in continental Europe as it would be expected from the milder winter design temperatures experienced in Wales. However recent research in to the implications of regional micro climates has also shown that there are significant concerns associated with the reliance on post air heating in regions dominated by low levels of irradiance due to prolonged cloud cover during the heating season. This situation is further exacerbated in exposed coastal and mountainous areas and additional verification of the climate data used in sizing the peak load is advisable if dispensing with a conventional heating system.

Previous research (Tweed and McLeod, 2008) using the PHPP model in the context of a terraced passivhaus in St Athan, a coastal location near Cardiff, provides an indication of the likely design tolerances that could be permissible for a Passivhaus in a coastal location with higher irradiance levels. Significantly, air infiltration rates of over 2 ach-1 @ 50 Pa and glazing U-values of up to 1.1 W/m2K did not (in isolation) prevent the dwelling from meeting either of the Passivhaus key performance criteria.

The research findings of Schneiders (2003) for Manchester and Ireland suggest similar findings with the Passivhaus standards being met using opaque U-values of 0.17 W/m2K and glazing U-values of 0.85 W/m2K. Similarly a study carried out on an apartment building in Värnamo, Sweden (Janson and Wall, 2007) indicated that it was possible to meet the Passivhaus peak heating load requirement in Southern Sweden using installed glazing U-values of 1.0 W/m2K .

Collectively these finding indicate that the passivhaus model is highly sensitive to localised climatic conditions in particular irradiance levels during peak load. It may well be possible to achieve the Passivhaus standard in Wales with a significant degree of tolerance in the opaque and glazed U-values where larger terraced row and multi-residential developments are built in areas of higher winter irradiance. Caution is needed in exposed cloudy micro climates particularly where small detached dwellings are concerned due to the relatively poor SA/V ratio. If confirmed through wider research studies, these findings could have implications for the design of passivhaus' where the local micro climate has a strong influence on the optimisation of the glazing ratio, built form and need for a supplementary heating system.

Procurement of locally sourced Passivhaus components is an important objective for regional economic regeneration based on a low carbon economy and the concept of a 'Welsh Passivhaus'. This research demonstrates however that the overall rate of heat loss from a PassivHaus dwelling is highly context dependent and as a result general design guidance should not be inferred from these preliminary findings.

ISSUES ARISING FROM ADOPTING THE *PASSIVHAUS* STANDARD IN WALES

We have established that in principle the Passivhaus standard is a viable starting point from which to develop zero carbon housing solutions. There are, however, other issues to consider in promoting this standard. These may be addressed by asking three broad questions. Firstly, can the construction industry in Wales build to this standard? Our initial exploration of appropriate construction technologies suggested the standard might be achieved best through modern methods of construction (MMC), relying primarily on timber framing skills and techniques. This was the method used on the first three passivhaus dwellings at Ebbw Vale, and despite the relative inexperience of the construction teams very high standards of air tightness were achieved. Wales is gradually beginning to develop an MMC capability but it unlikely to be able to deliver sufficient quantity of buildings for several years. However, the database of Passivhaus projects in Austria (IG Passivhaus Oberösterreich, 2008) shows that a significant number (30%) use masonry construction, suggesting that it should be possible to adapt and continue to use these traditional construction methods in Wales.

A second key question is: can we afford to build to this standard? Cost reviews carried out by Cyril Sweett (Cyril Sweett, 2007)] and the Gentoo Housing Association (Thompson and Morrison, 2009) suggests there are significant costs associated with building to low carbon and Passivhaus standards in the UK. Notably these vary according to the dwelling type—detached, terraced, or apartments. Cost will remain a major factor in delivering a high volume of new zero carbon housing, and design optimisation must therefore also be addressed from an economic perspective..

Finally, it is important to ask if people will be willing and able to adapt to living in Passivhaus dwellings? Thermal conditions in a Passivhaus building that is only heated by the ventilation system are finely balanced because the thermal capacity of the heated air is so low. Higher ventilation rates or higher internal heat gains are likely to destabilise the internal environment and so the occupants need to be able to 'fine tune' the building appropriately. There are also issues related to building maintenance. Comments in the Sullivan Report (Scottish Building Standards (2008) for example from Austrian contributors, who have direct experience of Passivhaus buildings; highlight the need for occupants, for to maintain the filters on MVHR systems to ensure adequate ventilation. Studies into the health implications of low ventilation rates are also being conducted and this in turn has implications for the specification of internal finishes and the need to monitor indoor air quality in air tight dwellings.

These questions and the research carried out here underline the need to conduct more detailed context specific research to discover the most practicable models for the wide spread role out of Passivhaus and zero carbon housing in Wales and the UK.

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