Building Performance Evaluation of a
14th Century Pargetted House:
Hygrothermal comfort and energy efficiency

Dr Chris Whitman,
Senior Lecturer, Course Leader MSc Sustainable Building Conservation.
Welsh School of Architecture, Cardiff University. WhitmanCJ@Cardiff.ac.uk
There exist many preconceptions regarding the energy performance of historic and traditional buildings. Building Performance Evaluation is therefore an important tool for sustainable conservation to inform decisions regarding ongoing use, aiming to satisfy the needs of the occupants, whilst maintaining heritage values.
Case Study: 14th Century Hall House with 17th Century Pargetting. Saffron Waldon, Essex, UK

Laser Scan of North elevation. Eastern cross wing to the left and western to the left. Source: (Author’s Own, 2017)

Distribution of surviving pre-1850 timber-frame buildings, showing infill materials and location of case study building.

Source: Author’s own based on (Historic England 2014, RCAHMW 2014)
Case Study: 14th Century Hall House with 17th Century Pargetting. Saffron Waldon, Essex, UK

Current Ground and First Floor Plans of case study, Saffron Walden, Essex, with overlay in blue showing layout of original hall-house. Source: (Author’s own based on drawings by (Kent, 2015))

Current Ground and First Floor Plans of case study showing division into two cottages no 27 (green) and 25 (pink). Source: (Author’s own based on drawings by (Kent, 2015))
Building Performance Evaluation (BPE) Methodology: In situ measurements

**Internal hygrothermal comfort (A)**
TinyTag Ultra 2 TGU-4500 sensors
Lascar® EasyLog® EL-USB-2 sensors
located in seven internal locations and one external measured at half hour intervals from 11/03/17-16/08/17.

**Pressure testing to measure airtightness (B)**
Minneapolis® blower door with analogue Magnehelic pressure gauges according to BS EN ISO 9972:2015 undertaken on 12/03/17

**Thermography (C)**
FLIR® B250 thermal imaging camera
Following Historic Environment Scotland guidance.
Undertaken 6:30am 12/03/17

**In situ U-value measurements (D)**
Huxeflux HFP01 heat flux plates, BS ISO 9869-1:2014 undertaken (12/03/17-02/04/17 and 15/12/19-22/01/20)
Building Performance Evaluation (BPE) Methodology: Digital Simulation

Energy demand
Digital simulation of both current energy demand and potential results of future energy retrofit actions were undertaken using the software DesignBuilder® Version 4.2.0.54, with measured U-values and airtightness imputed to improve accuracy. A climate file was created using the software Meteonorm® version 6.1 using the time period 1996-2005.

Frost Risk Analysis
Two-dimensional conduction of heat transfer was simulated using the software THERM® version 7.5.
Building Performance Evaluation (BPE) Results: Internal hygrothermal comfort

Percentage of time that hygrothermal comfort as defined by Givoni is achieved as recorded 11/03-16/08/2017. Source: (Author's own, 2017)

Percentage of time that hygrothermal comfort as defined by Givoni is not achieved due to low temperatures, high temperatures and high relative humidity. Source: (Author's own, 2017)

Psychrometric chart according to Givoni showing hygrothermal measurements as recorded 11/03-16/08/2017. Source: (Author's own, 2017)

Percentage of hours monitored

- Too cold
- Too warm
- Too damp


% of hours comfort achieved

## Building Performance Evaluation (BPE) Results: Pressure Testing - Airtightness

<table>
<thead>
<tr>
<th>Property</th>
<th>API (m³/h.m²)</th>
<th>ACR (/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>7.3</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>14.2</td>
<td>18.8</td>
</tr>
<tr>
<td>1&amp;2</td>
<td>58.6</td>
<td>56.6</td>
</tr>
</tbody>
</table>

API  Air Permeability Index  
ACR  Air Change Rate @ 50 Pa  
* Previous measurement undertaken in 2012
Building Performance Evaluation (BPE) Results: Thermography

External thermography undertaken unpressurised with an external air temperature of 10.5°C and internal temperatures between 13-22°C.

Internal thermography west cross-wing wall.

Internal thermography east cross-wing wall.
Building Performance Evaluation (BPE) Results: In situ U-Value

<table>
<thead>
<tr>
<th>Monitoring location</th>
<th>Wall thickness (m)</th>
<th>U-value (W/m2K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1*</td>
<td>0.170</td>
<td>0.85</td>
</tr>
<tr>
<td>M2</td>
<td>0.130</td>
<td>0.64</td>
</tr>
<tr>
<td>M3</td>
<td>0.170</td>
<td>1.29</td>
</tr>
<tr>
<td>M4</td>
<td>0.130</td>
<td>1.33</td>
</tr>
</tbody>
</table>

* Only measured over 5 days and so high error factor

Thermography of eastern cross wing showing location of monitoring positions. M1 & M2 monitored 12/03/17-02/04/17 and M3 & M4 monitored 15/12/19-22/01/20.

Source (Author’s own, 2020)
Simulated heating energy for current situation and a range of hypothetical retrofit actions at three different levels of airtightness. Existing situation shown in red. Source: (Author’s own, 2017)
Building Performance Evaluation (BPE) Results: Frost Risk

Simulations with THERM® version 7.5 of wall section through decorative pargeting showing temperatures.
Exterior temperature 0°C and interior 21°C. Source: (Author’s own, 2017)
Conclusions

The use of Building Performance Evaluation (BPE) has enabled a greater understanding of this historic property which can now inform the continuing decisions in its conservative repair. Keys findings are:

• That the pargetting appears to improve the U-value of the timber-frame wall, acting as an early form of External Wall Insulation (EWI).

• Conservative repair work removing inappropriate internal finishes has reduced the airtightness. The new finishes will hopefully rectify this.

• Improving airtightness and insulating roofs and floors could see a reduction in energy demand of 55%. However, the use of Internal Wall Insulation (IWI) on the pargetted walls would increase the risk of frost damage to this historically significant element and as such is not advisable.

The research presented in this paper has highlighted the role that BPE can play in understanding the complex performance of our historic built environment and the challenges that face us in balancing the conservation of heat and power and the sustainable conservation of our heritage.
Thank you

Dr Chris Whitman
Senior Lecturer, Course Leader MSc Sustainable Building Conservation.
Welsh School of Architecture, Cardiff University. WhitmanCJ@Cardiff.ac.uk