Building Better Buildings / UCL / Technology Strategy Board / Zero Carbon Hub
Monday, 15th February 2016

2 x BPE studies of Passivhaus domestic projects

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Introduction

bere:architects participated in 3 BPE projects that were funded by the Technology Strategy Board;

(1) **Camden House** (domestic)
(2) **Ebbw Vale social housing** (domestic)
(3) **Mayville / Mildmay Centre** (non-domestic)

This presentation focuses on the 2 domestic research projects
But first, why I wanted to do the BPE projects:

At the time, we were completing some of the UK’s first Passive House buildings... I wanted:

- To know if our buildings were performing OK
- To know if our buildings were healthy
- To record occupant responses to their homes
- To record whether PH methods “work in the UK”
- To know if we could do better next time
- Results with veracity given by academic partners

I was hopeful of good results, and I wanted to use the results to influence government, industry and the general public; To encourage them to put together a proper National Plan to address the environmental problems that the human species is causing through careless negligence.
Camden Passivhaus

PROJECT LEAD: BERE:ARCHITECTS
BPE PROJECT PARTNER: UNIVERSITY COLLEGE LONDON
DR IAN RIDLEY, LEAD RESEARCHER
SAMSUEL STAMP, CO-HEATING & FABRIC TESTS
WITH DR HECTOR ALTAMIRANO & DR BOB LOWE
TSB EVALUATOR: IAN MAWDITT
TSB LEAD: FRANK AINSCOW
Camden Passivhaus

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Camden Passivhaus

Ground floor plan

First floor plan
Camden Passivhaus

Building specification:

<table>
<thead>
<tr>
<th>Section</th>
<th>Insulation Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor slab</td>
<td>380mm wood fibre insulation</td>
</tr>
<tr>
<td>Walls</td>
<td>280mm mineral wool + 100mm wood fibre insulation</td>
</tr>
<tr>
<td>Flat roof</td>
<td>280mm PUR + 120mm mineral wool insulation</td>
</tr>
<tr>
<td>Sloping roof</td>
<td>380mm mineral wool insulation</td>
</tr>
<tr>
<td>Terrace</td>
<td>130mm PUR insulation</td>
</tr>
<tr>
<td>Heat Recovery Ventilation</td>
<td>PAUL Thermos 200DC</td>
</tr>
</tbody>
</table>
## Fabric Performance Data - first BPE results

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Design targets</th>
<th>Measured performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blower door test</td>
<td>0.6h-1 ACH @50Pa max</td>
<td>0.44h-1 ACH @50Pa</td>
</tr>
<tr>
<td>Tracer gas tests</td>
<td>0.6h-1 ACH @50Pa max</td>
<td>0.38 ±0.08h-1</td>
</tr>
<tr>
<td>Co-heating tests</td>
<td>63.6W/K</td>
<td>35±15W/K (too much sun)</td>
</tr>
<tr>
<td>In-situ U-value heat flux measurements</td>
<td>Ground slab 0.103W/m²K</td>
<td>56±5W/K (Sam Stamp’s 2nd test)</td>
</tr>
<tr>
<td></td>
<td>Lower wall 0.122W/m²K</td>
<td></td>
</tr>
<tr>
<td>Thermal bridge analysis</td>
<td>≤ 0.01W/mK at each junction</td>
<td>specific junction testing not possible but</td>
</tr>
<tr>
<td></td>
<td></td>
<td>analysed with infra-red thermography</td>
</tr>
</tbody>
</table>
“The indication is that the Camden Passivhaus is one of only a few co-heating tested dwellings that meets its design intent.”

“This is a positive reflection on the design and build quality of the house and is especially encouraging considering the low heat loss that was targeted here.”

Samuel Stamp, UCL Energy PhD research student
Energy consumption - **Specific Heat Demand**

Specific space heating demand  
- **(Design target)** 13.7 kWh/m²  
- **(Measured performance)** 12.1 kWh/m²

Camden Passivhaus space heating demand compared to the UK existing housing stock

* Benchmark taken from DomEARM
Energy consumption - **Electricity demand**

**Predicted** electricity consumption

![Predicted electricity consumption graph]

**Monitored** electricity consumption

![Monitored electricity consumption graph]

- Solar pump running continuously - fixed in late January '12
- Occupants away on skiing trip
Energy consumption - **Electricity & Heat**

**Predicted** energy demand:
- Sockets, blinds, appliances: 32%
- Space heating: 27%
- Lighting: 4%
- Boiler and pumps: 6%
- DHW: 25%
- HRV: 6%

**Measured** energy demand:
- Space heating: 25%
- Sockets, blinds, appliances: 25%
- Boiler and pumps: 16%
- Lighting: 11%
- DHW: 17%
- HRV: 5%
- Solar pump running continuously (fixed in late January '12)
- Lights on during the day!
Energy consumption - **Performance gap?**

Monitored vs. predicted space heating demand

```
Oct-11 | Nov-11 | Dec-11 | Jan-12 | Feb-12 | Mar-12
-------|--------|--------|--------|--------|--------
       | 0.0    | 1.0    | 4.0    | 4.0    | 1.0    |
       | 0.5    | 2.0    | 4.5    | 4.5    | 2.5    |
```

- **Monitored**
- **PHPP predicted**
Energy consumption - Comparison

Annual energy performance compared with benchmarks (DomEARM)

Annual CO₂ emissions compared with benchmarks (DomEARM)
Energy consumption - Comparison

Total gas and electricity consumption of UK domestic low-energy exemplars

- BedZed: 90 kWh/m²
- The Long House: 80 kWh/m²
- One Brighton: 72 kWh/m²
- Camden Passivhaus: 65 kWh/m²
- Princedale Road: 63 kWh/m²
Comfort - Psychrometric charts - winter

Average daily temperatures

living room  21 - 22 °C  
bedroom  19.6 - 20.4 °C
Comfort - Winter temperatures

Thermal comfort in January

- Living room
- Bedroom
- External

Date

Temperature (°C)
Comfort - Psychrometric charts - summer

Average daily temperatures

living room  23.5 - 24.5 °C
bedroom  21 - 22 °C
Comfort - Summer temperatures

Thermal comfort in June

Comparison of PHPP predicted and actual annual overheating

PHPP LIMIT

<table>
<thead>
<tr>
<th></th>
<th>PHPP predicted</th>
<th>Actual (&gt;25°C)</th>
<th>Actual (&gt;26°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October-March</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Summer (Jun-Sep)</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>
Comfort - BUS overall comfort
Comfort - Interior air quality

Average CO₂ concentration

- Living room: average 667ppm
- Bedroom: average 717ppm

Percent of time with particular IAQ standard in the living room:

- High IAQ (<750 ppm): 80.1%
- Medium IAQ (750-950 ppm): 15.5%
- Moderate IAQ (950-1350 ppm): 4.1%
- Low IAQ (>1350 ppm): 0.4%

Percent of time with particular IAQ standard in the bedroom:

- High IAQ (<750 ppm): 68%
- Medium IAQ (750-950 ppm): 0%
- Moderate IAQ (950-1350 ppm): 10%
- Low IAQ (>1350 ppm): 5%
Comfort - BUS perceived health

Less healthy: 1

More healthy: 7

© BUSMethodology 2011
Lime House, Ebbw Vale

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Larch House, Ebbw Vale

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Detailing for a really draught-free building

General arrangement airtightness strategy drawing

Eaves detail

Window / wall junction
Progressively staged detailed drawings

Window Jamb Progress Detail Stage 01

Window Jamb Progress Detail Stage 02
Progressively staged detailed drawings
Risk management

Good collaborative approach with site manager allowed risks to be identified early.

Wall / floor slab detail

Intermediate floor detail

Services penetrations
Never assume!

BT engineer compromised airtightness layer with incorrect installation; visiting on a day that the site manager wasn’t on site!
Careful design and commissioning of services

Heat recovery ventilation unit located in the cupboard on the ground floor in the Larch house
Heat recovery ventilation - filter maintenance
### What we were aiming for

#### Lime House
- **2010 Building Regs**
  - Using Part L Approved Document U-Value and ventilation requirements
- **Code level 3**
  - Using data from Holbrook Timber Frame Company
- **Code level 4**
  - Using data from Holbrook Timber Frame Company
- **Passivhaus standard (without PV panels)**
  - Using existing building data

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### How much does it cost to run a Passivhaus with PV?

<table>
<thead>
<tr>
<th>Building</th>
<th>Space Heating</th>
<th>Electricity</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime House</td>
<td>£520.35 (14665 KWh)</td>
<td>£208.64 (1557 KWh)</td>
<td>£728.99 (16222 KWh)</td>
</tr>
<tr>
<td>Larch House</td>
<td>£371.91 (9717 KWh)</td>
<td>£190.93 (1402 KWh)</td>
<td>£571.84 (11209 KWh)</td>
</tr>
<tr>
<td>Lime House</td>
<td>£332.61 (8407 KWh)</td>
<td>£197.65 (1475 KWh)</td>
<td>£530.26 (9882 KWh)</td>
</tr>
<tr>
<td>Larch House</td>
<td>£78.18 (1303 KWh)</td>
<td>£217.62 (1624 KWh)</td>
<td>£295.77 (2927 KWh)</td>
</tr>
</tbody>
</table>

**Passivhaus standard to Code level 5 - with PV panels on 48% of South facing roof**
- Using existing building data

**Passivhaus standard to Code level 6 - with PV panels on 80% of South facing roof**
- Using existing building data

- **Total**
  - Lime House: £696.65 (-759 KWh) from PV Feed in Tariff Payment****
  - Larch House: £1367.48 (-2543 KWh) from PV Feed in Tariff Payment****
Electricity consumption compared to typical

B.14) Time profile of electricity Consumption compared to EST average (Larch)

Average hourly profile of Electricity Consumption with average UK (EST study) profile

- Larch House
- EST typical UK
- Larch excluding Cooker
B.17) Time Profile of average PV generation, Export and Grid Import (Larch)

Average hourly profile of PV system
A.18 Time Profile of average PV generation, Export and Grid Import (Lime)
Excellent air quality results - Lime House

Lime House- Interior Relative Humidity (%) - 12th November 2012 - 10th December 2012

Note: the couple in the Lime house has a new born baby - 'drying clothes several times a day'.

The RH spikes which occur in the bathrooms during showers decrease fast, due to adequate ventilation.
Excellent air quality results - Larch House

Larch House-Interior Relative Humidity (%-12th Nov - 10th Dec 2012

* the clothes drying in the bathroom have a lower impact on the internal RH than the showers

* the occasional spikes in RH due to showers, and drying the clothes are quickly cleared by the ventilation system
Return on investment - if energy prices stable

3 bed Welsh Passivhaus - Charts from PHPP
Total Cost (Original build plus total running costs)

£180,000

£175,000
difference in estate quantities

Code 6 Passivhaus - PAYS BACK THE CAPITAL COST!

Code 4 Passivhaus

Code 5 Passivhaus

Building Regulations minimum standard

50 years

£35,000 difference in build-cost in estate quantities

£75,000 difference in 50yr value

£180,000

£175,000

£170,000

£165,000

£160,000

£155,000

£150,000

£145,000

£140,000

£135,000

£130,000

£125,000

£120,000

£115,000

£110,000

£105,000

£100,000

£95,000

£90,000

£85,000

£80,000

£75,000

£70,000

£65,000

£60,000

£55,000

£50,000

£45,000

£40,000

£35,000

£30,000

£25,000

£20,000

£15,000

£10,000

£5,000

£0.00

1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50
Return on investment - if 5% energy price-rise

3 bed Welsh Passivhaus - Charts from PHPP

Total Cost (Original build plus total running costs)

£300,000

£35,000 difference in build-cost in estate quantities

£170,000 difference in 50 year value!

£300,000
Return on investment - if 10% energy price-rise

3 bed Welsh Passivhaus - Charts from PHPP
Total Cost (Original build plus total running costs)

£1000,000

£900,000.00

£800,000.00

£700,000.00

£600,000.00

£500,000.00

£400,000.00

£300,000.00

£200,000.00

£100,000.00

£0.00

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 50 years

Building Regulations minimum standard

£870,000 difference in 50 year value!

£35,000 difference in build-cost in estate quantities

Code 6 Passivhaus

Code 5 Passivhaus

Code 4 Passivhaus

Code 5 Passivhaus minimum standard
What did I learn from the BPE projects?

Reassurance that some of the UK’s first PH buildings...

• Were performing OK
• Were closing the Performance Gap
• Were healthy for occupants and for the environment
• Occupants loved living in them
• PH methods do indeed “work in the UK”

Also:
• I got to learn a huge amount from academic partners
• I gained massive respect for the work of BPE academics - their work should be a national priority, and funded as such!
• I learnt that we can have a Zero Carbon Britain...
• I got ideas of the next steps towards this goal.
The very encouraging results of our BPE work, lead me to believe that it is possible, as a nation, to respond effectively to the climate change emergency.

If we inspire intelligent, responsible young people to join and lead the construction industry, and if we have a more responsible political environment, and a responsible attitude towards population growth, then we can build and retrofit both domestic and non-domestic buildings that will be capable of working successfully in a 100% renewable energy grid, along with electric transport and other aspects of daily life.