Building performance evaluation of dwellings

Issues relating to communal heating performance and thermal comfort

Michael Lim
Overview

– Introduction to BPE
– Instrumentation, measurements and data acquisition
– Example dwelling
– Features and findings
  • Fabric
  • Ventilation
  • Communal heating system
  • Energy use and benchmarking
  • Thermal comfort
– Lessons learned
– Concluding remarks
Introduction to BPE
Introduction to building performance evaluation

- A process of evaluating the performance of a building
  - Individual components
  - Interaction for compounded effect

- Components/aspects include
  - Building fabric
  - Building services and controls
  - Consumption of energy, fuel and water
  - Design intent, delivery, commissioning and handover
  - Occupant comfort, well-being and satisfaction
  - Environmental and function sustainability

- Ideally part of Soft Landings and carried out
  - Design stage
  - Construction stage
  - Post-construction/Pre-occupancy stage
  - Post-occupancy stage

- Objectives
  - Inform project development,
  - Enhance delivery,
  - Optimise performance,
  - Trouble shooting,
  - Provide feedback,
  - Inform future projects/lessons learned
Building performance evaluation scope

The study involved:

- Site-walkthrough and inspection
- Design and construction information review
- Building user surveys & developer post-construction interviews
- SAP assessment validation and energy benchmarking
- Thermography imaging & in-situ U-value
- As-build/as-installed system review and performance diagnostics
- Environmental condition measurements and monitoring
- Heat, gas, electricity and water consumption
- Appliances (small power) energy use
- Environmental and energy data for performance and thermal comfort analysis
Instrumentation, measurements and data acquisition
Instrumentation, measurements and data acquisition

- Environmental – external
  - Air temperature
  - Relative humidity

- Environmental - apartments:
  - Air temperature
  - Relative humidity
  - CO₂

- Resources - apartments:
  - Heat supply @ HIU (space & DHW)
  - Electricity:
    - MVHR
    - Lighting
    - Small power
  - Water consumption
  - Plug-loads
Instrumentation, measurements and data acquisition

- Eltek instrumentation for electricity, water, environmental measurement
- In-situ heat flux measurement for U-value
- Plug monitor for appliance load
- Temperature loggers
- Infrared thermometer for ad-hoc measurement
Instrumentation, measurements and data acquisition

- Smoke stick testing highlighting filtration and leakage paths
- Air tightness test – door seal and fan pressuring apartment (BSRIA)
- Thermography imaging – highlight cold bridging (BSRIA)
- Airflow hood with anemometer - MVHR flow rate measurement (BSRIA)
Example dwelling
Example dwelling – typical modern development
Example dwelling – typical apartment unit

- Main features:
  - High proportion glazing
  - High performance fabric
  - MVHR system
    - Air quality (base)
    - Moisture/odour removal (boost)
    - Summer by-pass
  - Openable windows for purge ventilation
  - Communal heating system (space heating and DHW)
  - HIU in service cupboard
  - Radiator or underfloor heating

- Might have:
  - Winter garden
  - External shading
  - Comfort cooling
Features and findings
Features and findings: Fabric performance - air tightness, U-values

Thermographic imaging revealed cold-bridging

Limited in-situ U-value by 3rd-party suggested external fabric performance close to as-designed

<table>
<thead>
<tr>
<th>External wall</th>
<th>Actual</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-value (W/m²K)</td>
<td>0.23</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Building performance evaluation of dwellings

May 2018
Features and findings: Ventilation - openable windows

- Openable windows and doors
  - Too close to soffit
  - Obstructed by curtain rail
  - Reduced free area

- Opening restrictor:
  - Limits opening hence free area
  - Override latch – purge vent

- Window frames, mullions and recesses:
  - Reduced free area
  - Worse for higher performance windows

- Occupant behaviour
  - Noise
  - Pollution
Features and findings: Ventilation - MVHR

- MVHR performance of 3 apartments:
  - Lower measured ventilation in 2 apartments than commissioned
  - Rates below BRegs Part F (2006) normal operation rates
  - Potential causes:
    - High pressure drop
      - excessive flexible ducts
      - narrow ducts
    - MVHR undersized
    - Poor installation/design
  - Potential moisture build-up, condensation and mold growth causing health issues
Features and findings: Ventilation - MVHR

Site inspection revealed
- Inlet and outlet grilles too close
- Clogged up inlet grille
- Dirty extract filter - schedule of installation, commissioning and frequency of maintenance
- Measured fan power higher than manufacturer claim of 0.59W/l/s

<table>
<thead>
<tr>
<th>Flat</th>
<th>State</th>
<th>Normal (W/l/s)</th>
<th>Boost (W/l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat 1</td>
<td>&quot;As-found&quot;</td>
<td>1.34</td>
<td>2.08</td>
</tr>
<tr>
<td></td>
<td>&quot;Clean&quot;</td>
<td>1.27</td>
<td>1.95</td>
</tr>
<tr>
<td>Flat 2</td>
<td>&quot;As-found&quot;</td>
<td>1.31</td>
<td>2.32</td>
</tr>
<tr>
<td>Flat 3</td>
<td>&quot;As-found&quot;</td>
<td>1.51</td>
<td>2.03</td>
</tr>
</tbody>
</table>
Features and findings: Communal heating system

- Central energy plant
  - Gas boilers
  - LZC tech – CHP, biomass, HP
  - Thermal stores
  - Pumps

- Secondary distribution pipework
  - Low loss header
  - Flow/return
  - Risers and ceiling voids
  - Insulated

- HIU/heat exchanger
  - Termination services cupboard
  - Space heating and DHW
  - Metering and billing
Features and findings: Communal heating system - performance

- **System efficiency**
  - Winter 2012 ~32%
  - Summer 2013 ~19%
  - Annual (Oct 2012 – Sept 2013) ~26%
  - Winter 2013 ~34%

- **2014 billing data**
  - 2,700 MWh gas consumed
  - 1,135 MWh heat metered at dwellings
  - efficiency improved slightly to 42%

- Average heat consumed per dwelling 6,602kWh/annum
Features and findings: Communal heating system - performance

- Measured data suggests:
  - Boiler efficiency ~60%
  - Distribution losses – 20-60%
  - System efficiency
    - At best ~ 50% (cold period)
    - Worst ~18% (warm period)
Features and findings: Energy use and benchmarking

- Heat and electricity use (Mar 2013 - Jun 2014) compared against SAP:
  
  - Lower heating demand
    - high performance fabric
    - heat gain from solar and pipework distribution losses
  
  - Higher fan energy due to lower MVHR fan efficiency although tempered by lower flow rates
  
  - Lower lighting energy
    - preference for standalone lighting (small power)
    - No strong link to good daylighting
Features and findings: Thermal comfort – causality

– Causes
  • Thermally efficient/highly-insulated façade
  • Secondary pipework (communal heating)
    o in riser
    o ceiling void
  • Flue riser
  • Services cupboard termination

– Effects
  • Heat losses from heating system conducts into internal structures and fabric
  • Warm
    o communal corridor
    o services cupboard
  • External façade barrier to heat dissipation
    o “Warm core”
    o Warm dwellings
    o Thermal comfort issues
Features and findings: Thermal comfort – dwelling heat gain

– Dwelling heat gain sources
  • “Warm core”
  • Warm services cupboard
  • Solar gains
  • Casual gains
  • Warm neighbours
    o Adjacent
    o Top and bottom

– Issues with UFH
  • High supply/return temp 60/50C
  • Insufficient underlay insulation
  • Controls issue
  • Downward radiation from slab
### Features and findings: Thermal comfort – mitigation measures

<table>
<thead>
<tr>
<th>Insulation standards</th>
<th>Network heat loss kWh/annum</th>
<th>% kWh reduction in heat loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>PART L 2006</td>
<td>144,416</td>
<td>0</td>
</tr>
<tr>
<td>ECA &amp; Y50 ENHANCED</td>
<td>130,174</td>
<td>10%</td>
</tr>
<tr>
<td>EN253 SERIES 1</td>
<td>120,256</td>
<td>17%</td>
</tr>
<tr>
<td>EN253 SERIES 2</td>
<td>105,171</td>
<td>27%</td>
</tr>
<tr>
<td>EN253 SERIES 3</td>
<td>89,492</td>
<td>38%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flow/return °C</th>
<th>Mean water temperature</th>
<th>W/m</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>80°C / 70°C</td>
<td>75°C</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>80°C / 50°C</td>
<td>65°C</td>
<td>6.2</td>
<td>17%</td>
</tr>
<tr>
<td>80°C / 30°C</td>
<td>55°C</td>
<td>5</td>
<td>33%</td>
</tr>
</tbody>
</table>

- **Mitigation measures**
  - MVHR extract in services cupboard
  - Insulated HIU and pipework
  - Window override latch for purge ventilation
  - Communal corridor mech vent
  - Riser vent and extract
  - Air conditioning/comfort cooling?

- **Design**
  - increasing insulation levels from existing standards
  - lower flow-return temperatures of distribution pipework
Lessons learned
Lessons learned

– In relation to the communal heating system

• Tendency for system oversizing

• Lack of detailed controls documentation

• Heat network adds a large heat loss, lowers efficiency

• Risk of uneconomical CHP (higher cost of heat) as
  o not able to sell surplus electricity – micro generator
  o distribution heat loss
  o unrecoverable operational cost – higher cost of heat

• Communal heating pipework results in higher core temperature

• UFH may contribute to warming of apartments below
Lessons learned

– In relation to the dwelling occupants

• Issues with heating system
  o Misunderstanding HIU is not a boiler
  o Switching off power to the HIU supplying the controls
  o “kWh” heat charges give no easy price comparison for users

• Issues with MVHR
  o Unaware of need for filter cleaning/changing
  o Perception that MVHR ensures total comfort
  o Use of MVHR boost misunderstood

• Reluctance to open windows + sub-optimal MVHR led to thermal comfort issues

• Manufacturers manuals too technical - need a ‘quick user guide’ approach
Concluding remarks
Concluding remarks 1

- As-build U-values shown to be in line with design
- Significantly better air permeability than design
- Lower actual ventilation rates than BReg's Part F for some apartments
- Overall, the heat consumed by monitored apartments 40 to 65% less than SAP

- Communal heating system
  - various installation and controls issues led to poor performance
  - poor overall system performance partly due to distribution losses
    - could be a result of insufficient pipework installation quality and/or the standards of pipework insulation
Concluding remarks 2

– Issues affecting thermal comfort:
  • High performance external fabric ‘traps’ heat
  • Communal heating heat losses warm core
  • Low MVHR ventilation rates
  • Poor free area of openable windows
  • Insufficient external shading
  • High glazing proportion - excessive solar gain
  • Occupant reluctance opening windows

– Distribution pipework - incentive for lower f/r temperature or decentralised system?
  • dominates system capital cost
  • losses are significant (efficiency penalty)
Thank You

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