BUILDING PERFORMANCE EVALUATION CASE STUDY
RACECOURSE

Photo: Gentoo

Building Performance Evaluation Team

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This case study examines two Passivhaus bungalows at the Racecourse development: one mid-terrace and one end-terrace. The evaluation of these dwellings was conducted under the Technology Strategy Board's (TSB) Building Performance Evaluation programme. To determine the effectiveness of the design and delivery strategy at the Racecourse, real fabric performance indicators were tested to compare these results with anticipated performance. The project team followed the TSB protocols for fabric and services testing, conducting the following examinations:

- Thermographic survey
- In-situ u-value tests
- Airtightness tests
- Coheating test
- Services commissioning checks
- Design and Construction review
- Occupant induction review

Additionally the BUS survey was used to capture occupant perceptions about their dwellings.

The results from this evaluation are positive. As-built, the dwellings achieve Passivhaus standards. The building fabric has exceptionally low heat loss and air permeability, the building services have been commissioned correctly and the occupants are generally happy with their homes.

Design and Construction

Racecourse is a development of 28 bungalows for housing senior people, located in a council estate in Houghton-le-Spring, Sunderland, and built in 2011. The area is part of a Citywide Renewal Plan aiming to replace older housing stock with around 4,000 high quality homes. Of the 28 bungalows, 25 are terraced (8 end-terrace and 17 mid-terrace) and three are detached. The terraced bungalows are designed to Passivhaus standards and either level 4 or 5 of the Code for Sustainable Homes. The detached units are designed for mobility impaired tenants, and although they have been built to the same fabric and services' standards as the terraced dwellings, due to their more challenging dwelling form, they are not designed to be Passivhaus certified.

Each bungalow has a total floor area of 66m^2, comprising an open-plan living and kitchen area, a mezzanine which functions as a plant room and loft space, and two bedrooms.

The external walls were built using pre-fabricated timber-frame cassettes filled with 300mm insulation. Walls were then externally clad with 15mm bitroc and either brick or render. Internally, the external walls have a 47mm insulated service void lined with 25mm plasterboard. The ground floor is reinforced concrete slab-on-ground construction, with 300mm insulation above the slab and then a 50mm screed. The roof is constructed using pre-fabricated timber-frame cassettes filled with 450mm of insulation and clad in clay roof tiles.

All windows are triple glazed, low-e krypton filled units with warm edge spacers and thermally broken frames. The doors are aluminium faced composite (aluminium/insulation/timber) with thermally broken frames.

A detailed strategy for achieving the air leakage target of ≤ 0.6 h^{-1} @ 50Pa was developed and carried out.

The predicted fabric and services performance figures are listed below in Table 1.

Table 1. Design Targets

Whole house heat loss (Leeds Met calculation)	43.4 W/K (Dwelling 1) 36.6 W/K (Dwelling 2)
Air permeability (design SAP)	0.6 m^{3}h^{-1}m^{-2}@ 50Pa
Air tightness (design Passivhaus)	0.6 h^{-1} @ 50Pa
U-value: roof (as-built SAP)	0.08 W/m^{2}K
U-value: walls (as-built SAP)	0.10 W/m^{2}K
U-value: ground floor (as-built SAP)	0.08 W/m^{2}K
U-value: windows and doors (as-built SAP)	0.70-0.90 W/m^{2}K
Y value (as-built SAP)	0.02 W/m^{2}K
MVHR heat exchanger efficiency (SAP Appendix Q)	85%
MVHR fan Specific Fan Power (SAP Appendix Q)	0.5 W/l/s

A whole house MVHR system has been installed in the loft space of each bungalow. As a conventional wet, central heating system is not required because the space heating demand for each dwelling is very low (being built to

Passivhaus standards), space heating is provided via a small, low temperature hot water heater battery installed in the MVHR ductwork. In addition to the heater battery, a heated towel radiator is provided in the bathroom and a small radiator has been installed in the drying cupboard.

The domestic hot water system utilises twin coil hot water cylinders in the mezzanine plant area of each bungalow, with heat input from the communal heat main and the solar hot water system. 3m^2 roof-mounted collectors have been installed on the South-facing roof slope of each bungalow.

Throughout construction the project architect and contractor worked closely to ensure that airtightness targets were fulfilled, the designs were buildable, and the project met quality assurance measures. Additionally the Passivhaus designers held knowledge transfer events for the services installation engineers, who then briefed the maintenance engineers on maintenance requirements.

A number of strategies were used to reduce the risk of thermal bypass within the timber-frame cassettes. For example, the specification stated that tuck ends should be avoided, and the insulation thickness was specified to be 10% greater than the available cavity to achieve a tight but even compression; this became known as an ‘over-stuff’.

Real Performance

The evaluation team visited the site during construction, noting anything that could impact fabric performance and airtightness.

The Coheating test was undertaken on one end-terraced (Dwelling 1) and the adjacent mid-terraced (Dwelling 2) bungalow between the 11th November and the 21st December 2011, in accordance with the TSB adopted protocol developed by Leeds Met[1].

The measured and predicted heat loss coefficient for both dwellings are very close to one another, with the difference in heat loss coefficient being within the range of the error associated with the test, as shown in Table 2.

1 Note this protocol has now been updated http://www.leedsmet.ac.uk/as/cebe/projects/iea_annex58/whole_house_heat_loss_test_method(coheating).pdf

In context, the measured and predicted whole house heat loss for both dwellings represent the two best performing dwellings out of a sample of 21 other new build Coheating tests undertaken by Centre of the Built Environment at Leeds Met over the last decade.

The table below compares the design targets with the measured values for the fabric tested bungalows. Overall the dwellings, as constructed, are very airtight and well insulated, and perform close to the design targets.

Table 2. Closing the Performance Gap

	Predicted	Measured [Leeds Met]
Whole house heat loss coefficient	43.4 W/K (Dwelling 1) 36.6 W/K (Dwelling 2) [Leeds Met calc]	46.7 W/K (Dwelling 1) 38.1 W/K (Dwelling 2)
Air permeability	0.6 m^{3}h^{-1}m^{-2}@ 50Pa [design SAP]	0.89 m^{3}h^{-1}m^{-2}@ 50Pa (Dwelling 1) 1.31 m^{3}h^{-1}m^{-2}@ 50Pa (Dwelling 2)
Air tightness	≤ 0.6 h^{-1} @ 50Pa [design PH]	0.49 h^{-1}@ 50Pa (Dwelling 1) 0.50 h^{-1}@ 50Pa (Dwelling 2) [extenal contractor tested for PH certification]
Ground floor	0.08 W/m^{2}K [as-built SAP]	0.07-0.18 W/m^{2}K 0.10 W/m^{2}K [mean]
Wall	0.10 W/m^{2}K [as-built SAP]	0.08-0.23 W/m^{2}K 0.12 W/m^{2}K [mean]
Roof	0.08 W/m^{2}K [as-built SAP]	0.09-0.20 W/m^{2}K 0.13 W/m^{2}K [mean]
Window (centre-pane)	0.80 W/m^{2}K [as-built SAP]	0.56-0.78 W/m^{2}K 0.68 W/m^{2}K [mean]

A number of heat flux plates were located throughout Dwellings 1 and 2 to obtain in-situ measurements of the U-values of various elements of the building fabric. Measured U-values generally compared favourably with design values.

Air pressurisation tests and leakage identification was undertaken by Leeds Met on the two studied bungalows. The bungalows form part of a terrace of 7 properties, with the primary air barrier around the entire terrace as a whole, rather than around each individual bungalow. Tests were conducted twice: before the Coheating test (after Practical Completion), and immediately after the Coheating test. Although very tight by UK standards, the figures obtained for both dwellings are higher than the designed tightness found on the SAP worksheets.

The Leeds Met research team undertook flow rate measurements on Dwellings 1 and 2 in January 2012. The measurements indicated that the whole house supply and extract rates were balanced, but that the total measured supply and extract flow rates were higher than the design rates, in some cases by almost 50%. It was determined that the greater air flows were most likely because the 7 factory pre-set speed settings of the MVHR units could not be changed on-site.

The space heating systems for the examined dwellings were commissioned in November 2012. Observations of the installed space heating system indicated that the specified system, including the communal boiler and distribution pump, space heating systems in the dwellings, and the majority of the exposed pipes in the loft space were properly insulated.

27 BUS questionnaires were distributed to residents, of which 21 were completed and returned. On the whole, occupants were satisfied with their dwellings, and had positive feedback for the majority of the questionnaire categories.

Key Observations

1. Fabric tests showed both dwellings to be very airtight by UK standards, with measured U-values close to the design U-values, and no significant areas of unexpected heat loss.
2. The Coheating tests showed very little difference between the measured and the predicted heat loss coefficient of both dwellings.
3. Building services appear to have generally been installed to a high standard and commissioned correctly.
4. The design and construction team experienced a number of challenges during the construction process. For instance, two timber-frame manufacturers ceased trading during the project, and there were difficulties sourcing a number of the building products. Despite these challenges, the dwellings were constructed pretty much as intended.
5. Feedback from the client and tenants has identified potential overheating in some homes. This is thought to be a result of occupants keeping windows closed during summer, which has been traced back to early guidance concerning the MVHR given to occupants.
6. Overall the residents feel the dwellings are of high quality, enjoy living in them and are happy with their performance.

Key Lessons

1. Careful design alongside the appropriate quality control systems, such as those required to attain Passivhaus Certification, can help deliver dwellings that begin to bridge the Performance Gap.
2. There is no standardised method of commissioning particular building services; the development of a standardised method would enable comparability between dwellings.
3. The high surface area to volume ratio of a bungalow is disadvantageous in Passivhaus design. This results in additional heat losses that have to be compensated by increased performance specifications. A more efficient form factor enables lower performance specifications to be used, and can reduce capital costs.

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