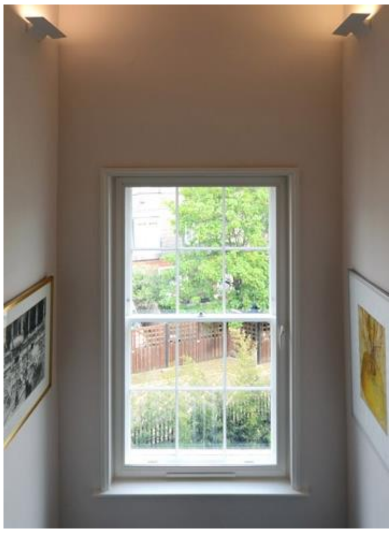
1.0 CLAPHAM RETROFIT, LONDON

Overview

This private, domestic project involves the deep retrofit of a semi-detached, 4-storey townhouse in a well-kept residential area. Dating from c.1840, the 170m^2 property is Grade II listed and the original construction comprises solid brick walls (c.225-440mm), suspended timber floors, a timber and slate roof and single-glazed timber windows.

The property has been retrofitted using a whole-building approach to achieve extremely high standards of thermal performance and airtightness, adopting materials and detailing complementary to the building's fabric and historic significance. The space heating demand has been reduced by over 75%, while internal temperatures and relative humidity remain steady and comfortable. The project achieved the AECB[1] Silver Standard, was a Finalist in the 2014 AJ[2] Retrofit Awards, and won the 2016 CIBSE[3] Building Performance Award for Residential Building of the Year.



[1] Association for Environment Conscious Building.
[2] Architects' Journal.
[3] Chartered Institution of Building Services Engineers.

1.1 Measures & impacts

By following a meticulous, whole-house approach the space heating demand has been reduced by over 75%. Energy demand has dropped from 180 to 40kWh/m^2/yr, while internal temperatures and relative humidity remain steady at c.20°C and c.50-55% respectively. Airtightness has improved from 9.6 to 1.8ac/h. The following table outlines the measures implemented.

Element	Measure
Roof	▪ Renovation: new slates + vapour-permeable membrane ▪ Ceiling-level insulation: cellulose fibre[4] on vapour-permeable membrane ▪ Insulated, draught-proofed loft hatch

Walls	External:
	▪ Cement pointing & ground-floor render removed & replaced with lime
	▪ Drainage & permeable finishes to wall perimeters
	▪ External insulation below ground: 150mm Styrofoam
	Internal:
	▪ Gypsum plaster removed
	▪ Joist ends treated with boron
	▪ Lime plaster to all external walls prior to insulation
	▪ Basement walls lined with cavity drain system[5]
	▪ Insulation, using multiple systems according to localised performance needs & including:
	  ▪ Woodfibre[6]
	  ▪ Aerogel[7]
	  ▪ PUR rigid foam boards with capillary-active design[8]
	  ▪ Calcium silicate boards[9] (between floor joists)
	  ▪ Perlite beads[10] (stair stringer only)
	▪ Finished mainly with magnesium board, lime plaster & breathable paint

Basement floor	▪ Lined with cavity drain system as per basement walls ▪ Insulated with vacuum insulated panels (30mm) below screed
Windows	▪ Original windows retained, overhauled & draught-proofed ▪ Secondary glazing added (double glazed) ▪ Reveals insulated (e.g. shutter boxes filled with cellulose fibre)
Airtightness	▪ Doors & windows overhauled ▪ Internal lime plaster to all external walls prior to insulation ▪ Careful airtightness taping to all joints, junctions & joist ends ▪ Service penetrations with grommets
Space & water heating	▪ Gas central heating + radiators ▪ Multi-fuel stove: Morsø S11-40
Ventilation	▪ Continuous MEV (mechanical extract ventilation) to all wet rooms
Lighting	▪ LED
Other	▪ Solar thermal array in double-pitched roof valley

[4] Warmcel.
[5] Platon P5.
[6] Gutex Thermoroom.
[7] Thermablok.
[8] iQ-Therm.
[9] Calsitherm.
[10] Silvapor.

1.2 Approach & process

This project targeted a very high energy performance while protecting the historic character of a listed building. Adopting a Passivhaus[11] methodology (but not seeking EnerPHit[12] performance levels), the design followed a fabric-first approach focusing on high levels of insulation and airtightness. Specification and detailing were informed by extensive testing and research beforehand, to identify appropriate measures compatible with the building's fabric and historic significance, and ongoing monitoring is in place to inform this and future projects. The result is a high-performance dwelling, with no visible evidence of insulation or airtightness measures, and with an internal environment beneficial to the health of both the building and its occupants.

An initial building performance survey was carried out in 2012, including U-value monitoring, an air leakage test, a thermographic survey and interstitial temperature and moisture gradient monitoring. These provided accurate, site-specific baseline figures and details of current thermal performance, and avoided the need to rely on generic assumptions: some walls, for example, were found to have a U-value of 0.88 W/m^{2}K, markedly better than calculated or default figures. The thermographic survey identified weak spots are openings and floor voids; the temperature and moisture monitoring identified a reasonable margin of safety between the temperature and dew point gradients. Brick permeability testing was also carried out, which informed the subsequent insulation strategy.

The specification process for the insulation strategy was critical, and included consideration of the following key issues: hygrothermal condition of existing building fabric; historic significance, character and special interest; local climate & microclimate (including driving rain & solar radiation on different orientations); existing wall build up (including presence of cementitious materials) & available depth for insulation; thermal performance; vapour permeability; hygroscopicity & moisture buffering; capillarity; management of internal humidity and air quality; buildability, storage & material processes; fire rating; reversibility; cost; compatibility with thermal bridging, airtightness & ventilation strategies; and embodied energy & global warming potential (GWP).

The outcomes of this thorough planning process led to the use of predominantly moisture-open materials to insulate the property. Before these could be installed, however, maintenance works were required to ensure a sound building base: these included general repairs and the removal of cementitious materials and their replacement with moisture-open, lime-based equivalents. Joist ends were treated with boron to resist moisture build-up. Multiple insulation materials were chosen, to fulfil different functions, for example:

- Woodfibre meets all the moisture-open criteria: it is vapour permeable, allowing water vapour to pass through it; it is capillary active, so direct bonding to the wall surface assists with wicking moisture away from the masonry; and it is hygroscopic, enabling it to absorb excess moisture in the air and thus act as a 'buffer' during periods of high relative humidity;
- Aerogel is high-performance but slim in profile, enabling insulation to areas where space is restricted such as beneath cornices or in window reveals; it is also vapour permeable
- Perlite beads allowed the relatively inaccessible space between the stair and external wall to be insulated, avoiding a potential thermal bridge;

[11] Passivhaus basic principles.
[12] EnerPHit certification criteria for refurbished buildings.

- Calcium silicate enabled the restricted space in the floor-wall junctions to be insulated; the choice of a very capillary-active insulation material near the joist ends ensures that any liquid moisture can be rapidly wicked away;
- Styrofoam and vacuum insulated panels below ground level met the requirement for a moisture-closed approach in these areas.

The application of poured lime plaster prior to insulation provides an effective, relatively low-tech but vapour-permeable airtightness layer, and enables relatively inaccessible zones to be included (e.g. a 30mm gap between a joist end and brick wall). 'Intelligent' vapour-permeable membranes and services grommets were also used, and airtightness tapes were applied with great care to avoid gaps.

While the use of predominantly moisture-open materials reduces any moisture-related risks either on or in building fabric, such a comprehensive approach to insulation and airtightness makes effective ventilation essential to ensure high internal air quality. Continuous mechanical extract ventilation fulfils this function, pulling damp, stale air out of the property and replacing it with fresh air via natural infiltration. The secondary-glazed windows also have vents on them to provide additional/controlled infiltration if required.

With numerous different insulation systems, building performance monitoring provides an important learning platform for this and future projects. Monitoring equipment was integrated into the design, with wireless hygrothermal sensors[13] and other monitors being installed at multiple points within the building (walls, chimney flues, loft spaces, secondary glazing cavities & rainwater downpipes) to record data including internal & external temperature, relative humidity and wood moisture equivalent (WME). Manual monitoring has also taken place: an area of relatively thick (200mm) woodfibre insulation was drilled and physically inspected to check there was no evidence of moisture build-up or mould. Such comprehensive monitoring has also allowed the impact of previous building defects to be recorded: prior to the works blocked rainwater goods had saturated one area of North-facing wall, and the monitoring established that this area of masonry took nearly a year to drop below 100% saturation.

The invasive nature of the works required the building to be unoccupied during the retrofit project. The (private) clients moved into the house in 2013, and no significant problems have been reported; some condensation has occurred between the primary and secondary glazing in one top-floor room, but modifications have been made and the area will be tested in the winter of 2017-18. The designers have maintained a relationship with the occupants: this not only enables any issues to be identified and resolved at an early stage, but also supports ongoing learning from this ground-breaking project.

Such a detailed and lengthy retrofit project inevitably carries a high cost. This was an expensive project – partly due to the multiple building defects that had to be addressed to make the building 'retrofit ready' – and this level of retrofit is not replicable on a widespread scale. However, the project is recognised as one of the best UK examples of high-quality retrofit in a historic building, and provides invaluable lessons in driving higher-quality retrofit. The challenge for widespread whole-building retrofit is to follow the principles and apply them to other traditional buildings at an affordable scale.

[13] Hygrotrac.

1.3 Example details

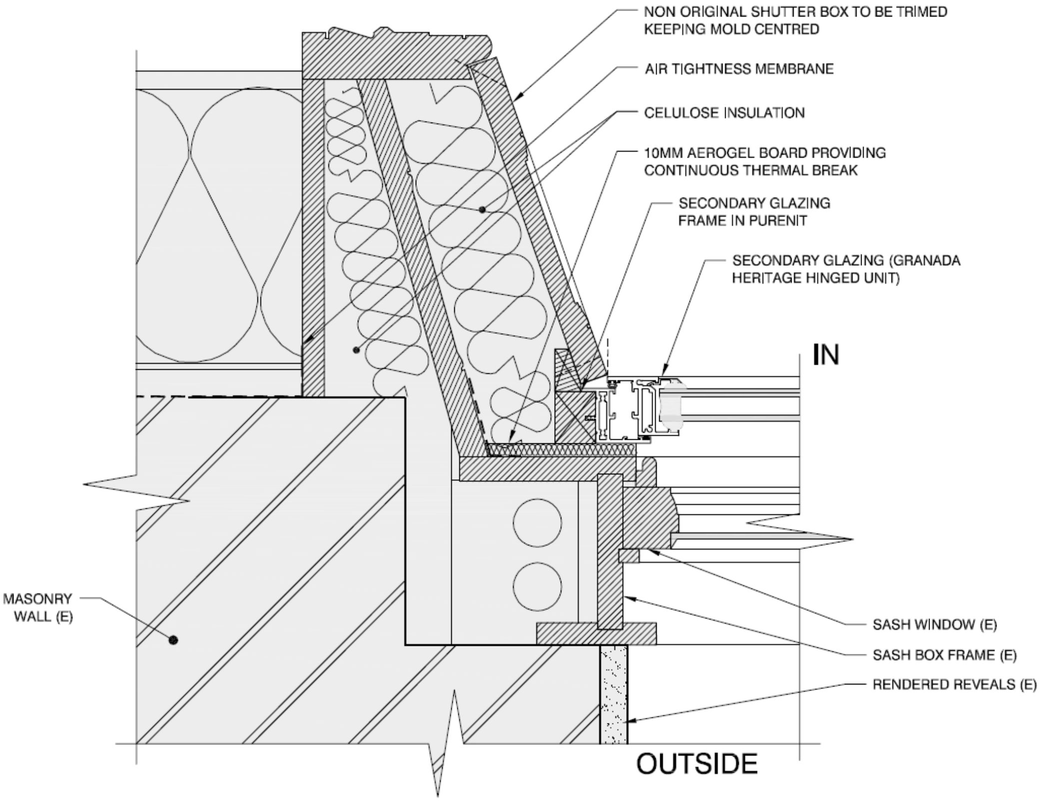


Fig. 1 Secondary glazing with shutter boxes (© Arboreal Architects)

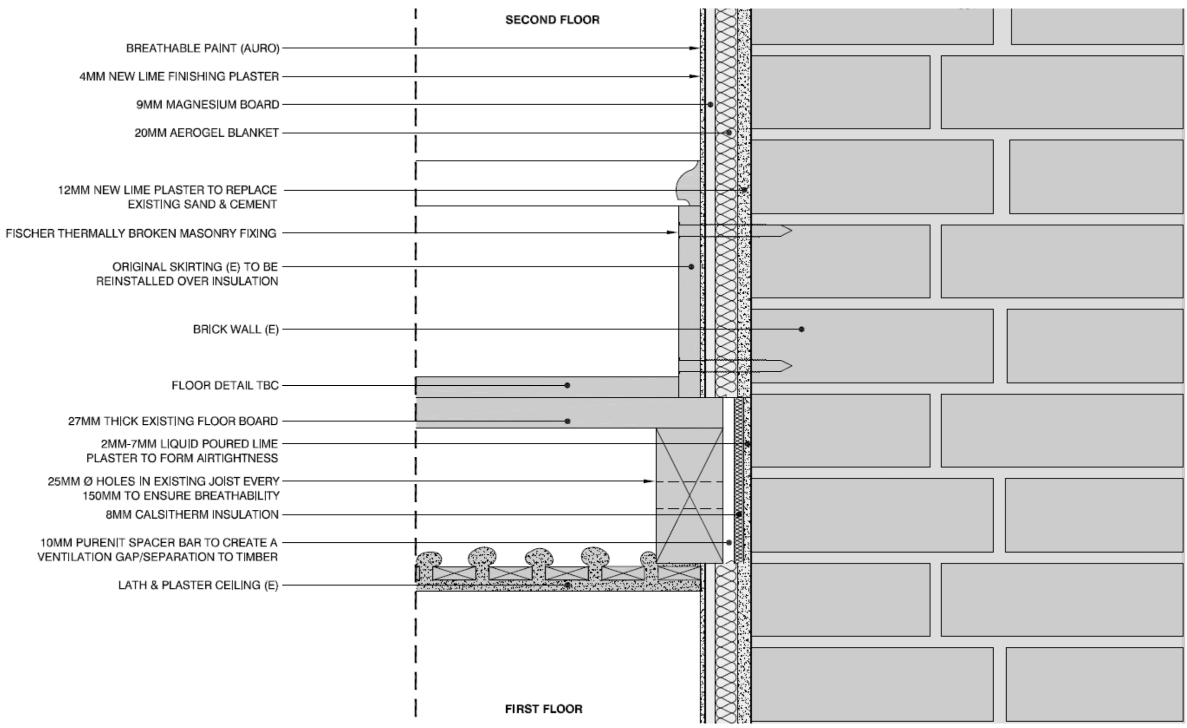


Fig. 2 Insulation & airtightness continuity through floor-wall junction (© Arboreal Architects)

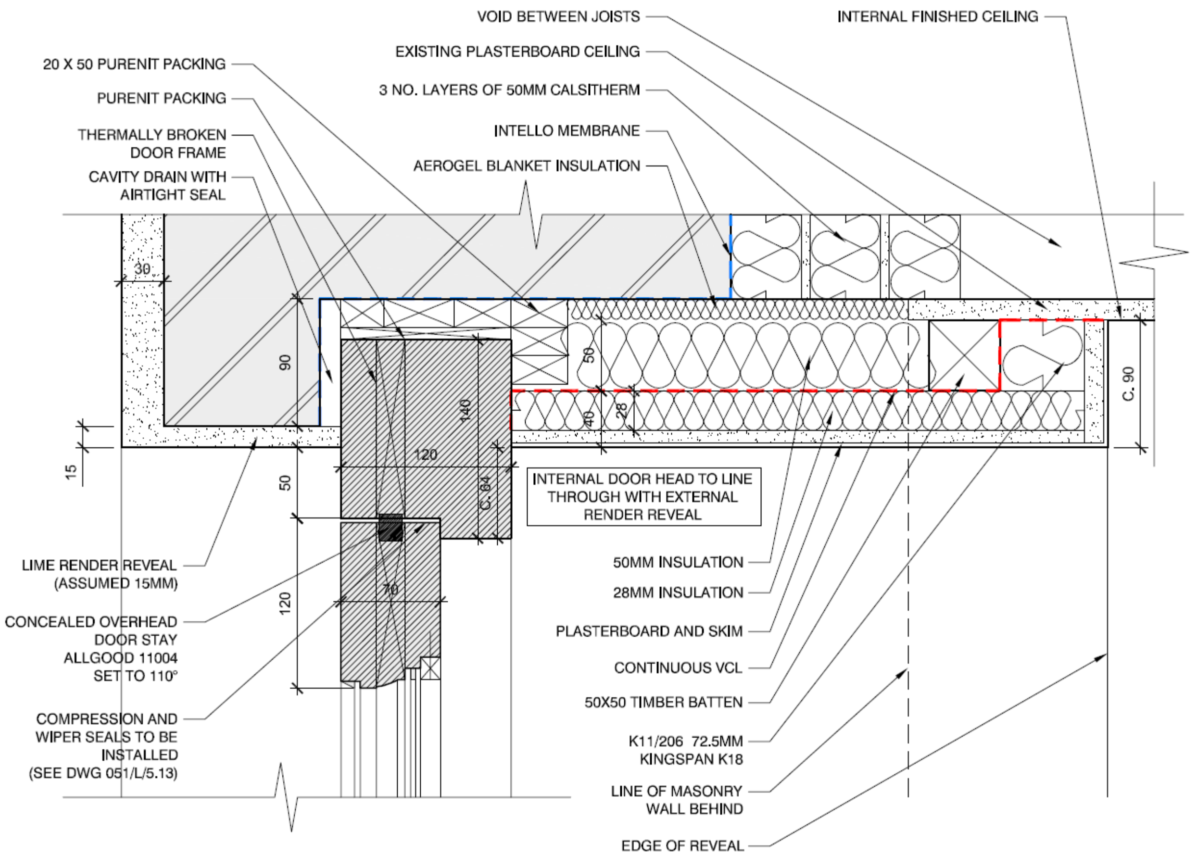


Fig. 3 Door head (© Arboreal Architects)

1.4 Further information

- Harry Paticas, Arboreal Architecture
- Low Energy Building Database