CarbonLite standards on eco-renovation

In summer 2007, AECB members, Simmonds Mills Architects began design work on Grove Cottage which was built as a detached house in 1869 for a railway carriage inspector on a strip of development land alongside the rail route from Hereford to South Wales. Responding to a brief that required additional bedroom space, more practical domestic working and storage space and a better relationship between the habitable spaces and the garden to the east. This article, by Andy Simmonds (co-owner of the cottage and partner in Simmonds Mills), and Alan Clarke (services design) concentrates mainly on the refurbishment elements of the project.

The street in which Grove Cottage now resides, Portfield Street, follows an approximate north-south axis. Grove Cottage is on the east side of the street with garden behind. Subsequent Victorian developments in the street were a mixture of detached, semi-detached or terraced homes. The house built to the north is not attached; there is a 25mm gap between external walls. These solid brick walled buildings used either plain or decorative brickwork, some have been subsequently painted, some rendered and others left with their original decorative brickwork. Original roofing in the street is predominantly slate. Grove Cottage itself is a 90m^2, two bedroom property with a 30m^2 basement. In 2005 the house was bought by Andy Simmonds and Lorna Pearcey for £160,000, with a further £5,000 spent making alterations and improvements to accommodate their 3 year old son, Milo and imminently expected twin boys, Otto and Raimi. This work included only one element of insulation – a 'temporary' 300mm of cellulose insulation laid over approximately half the attic floor to top up the existing 50mm of old glass fibre laid between the attic joists.

After the birth of the twins plans for further work went on hold, and heat and power related emissions continued apace. The existing heating system included a natural gas fired boiler and radiators with hot water provided by a separate gas water heater. Cooking is based on a gas hob and electric oven. During a 12 month period (during which space heating was occasionally left on low overnight to keep the new born twins warm) utility bills showed that to heat and power the house required converted to primary energy:

- 28,000kWh/yr from natural gas
- 13,800kWh/yr of electricity

  That's 5.5 tonnes for the gas, and 7.5 tonnes for the electricity - together emitting 13 tonnes of CO_2/yr

It was difficult achieving and maintaining an even temperature in such a poorly insulated and draughty house and the expenditure of all this energy never resulted in a healthy or thermally comfortable environment! We decided that the time had come for a radical improvement to the insulation and energy standards of the house. To meet our own expectations, a successful outcome for the project would result in whole house CO_2 emissions for heat and power being reduced by approximately 80 - 85% compared to the average measured performance of a typical UK house of the same size.

Design and the planning application

Work began on a design that applied low-energy, low-carbon 'design rules of thumb' and used design skills, informed by Andy's three year professional involvement (he is the AECB's executive officer) in the development of the CarbonLite Programme (see top right next page) to develop designs up to a planning application. Simmonds Mills also relied on energy advice sought from Alan Clarke

*** Primary energy - what is it?**

Primary energy is the energy embodied in natural resources prior to undergoing any conversions or transformations in power plant. For the purpose of discussion here, energy lost in delivery and consumed at the point of use, is added.

The AECB's CarbonLite Programme (CLP)

What is it and how can it help to reduce energy consumption in our buildings?

The CarbonLite Programme is a step-by-step guide to creating and using buildings with low energy use and CO_2 emissions. It is aimed at clients, developers, design teams, builders and building users. It is designed to fill the gap between the aspiration to deliver buildings with better energy and CO_2 performance and the often more disappointing reality. It explains the reasons for adopting robust, whole building energy standards, and provides straightforward and transparent guidance and advice on how to achieve them. www.carbonlite.net

CLP steps	Standard	Space heating energy	Primary energy*	CO_2 emissions
1	Silver	40 kWh/m^2yr	120kWh/m^2yr	22kg/m^2yr
2	Passivhaus	15kWh/m^2yr	120kWh/m^2yr	No explicit limit
	Passivhaus (in UK context)	15kWh/m^2yr	78kWh/m^2yr	15kg/m^2yr
3	Gold	15kWh/m^2yr	58kWh/m^2yr	4kg/m^2yr

Table 1. The three CarbonLite energy standards, as applied to a typical dwelling.

(*for heating, hot water and electricity)

for the Passivhaus (PHPP) and services design, David Olivier (design advice) and Peter Warm (modelling of construction junctions for thermal bridging). The energy performance target was AECB CarbonLite step 2, the Passivhaus energy performance standard, plus further guidance on how to ensure that CO_2 emissions are minimised. It was felt that a result somewhere within the range of performances reported by the Passivhaus Institut for continental Passivhaus refurbishments should be achievable. It was not expected that the Passivhaus new build target for specific space heating demand of 15kWh/m^2yr would be reached, however it was hoped that a demand of no more than 22kWh/m^2yr would be possible. This set extremely challenging targets for improving the thermal performance of the building fabric through high levels of insulation, 'thermal bridge-free' junctions between walls, floors and roofs etc and achieving a very airtight building envelope of 0.75m^3/m^2hr.

At the pre-planning stage it was anticipated that U-values below the maximum values specified in the Passivhaus standard/CLP step 2 would probably be required. Given the likely extent of heat loss from both hard to deal-with thermal bridges associated with the existing house - such as foundations, or junction with neighbouring house - and difficulty with incorporating high levels of insulation in existing floors it was thought that much lower U-values for walls and roofs would be able to compensate. Another reason for requiring lower U-values for elements was associated with the new extension; the refurbished house and its new extension do not follow a 'classic' compact Passivhaus building form but instead have a relatively high surface to volume ratio. This form was dictated by pragmatic and planning related restrictions (e.g. neighbour's windows in boundary wall), as well as the client's architectural preferences. Therefore walls and roofs were drawn 'thick' to ensure that realistic construction depths and overall roof heights and increases to wall thicknesses were represented in the planning drawings, avoiding problematic issues later on that might have compromised insulation thicknesses.

Planning permission was unanimously approved mid July 2008 by the local area planning committee, and the plans were warmly welcomed by the council executive and local

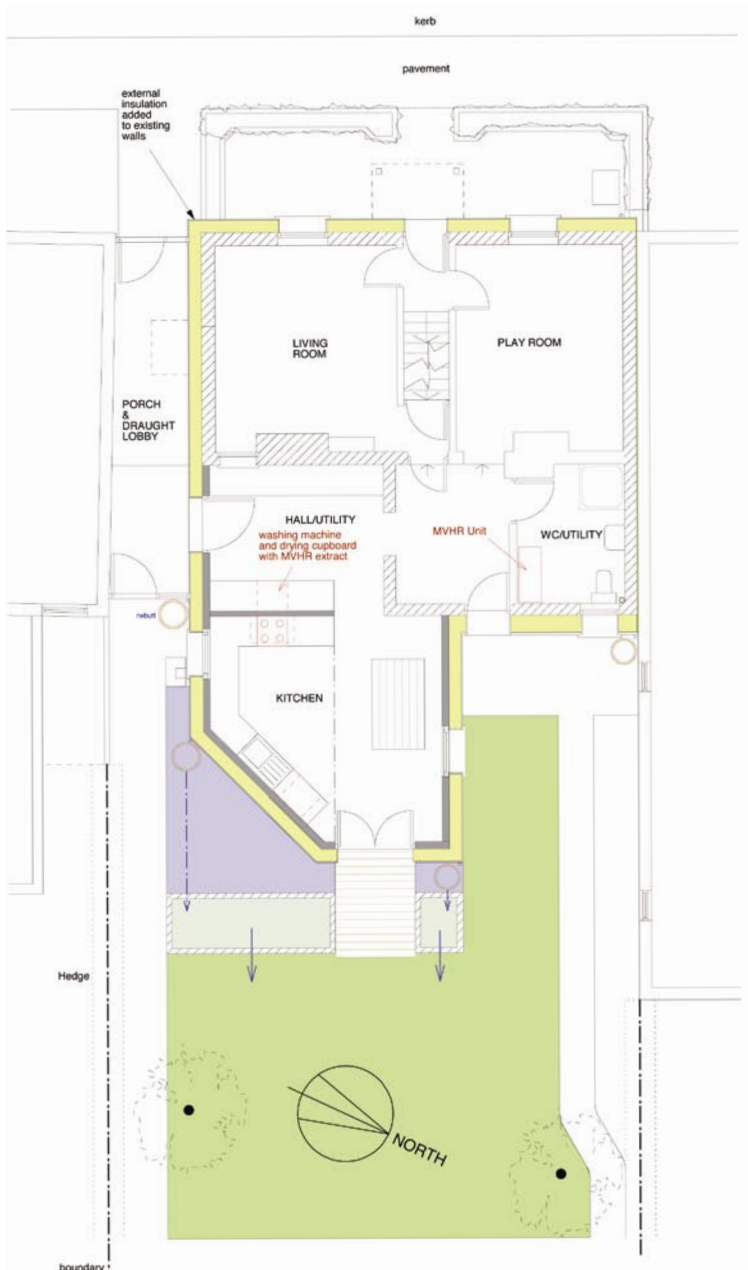


Fig 1. New ground floor and garden plan.

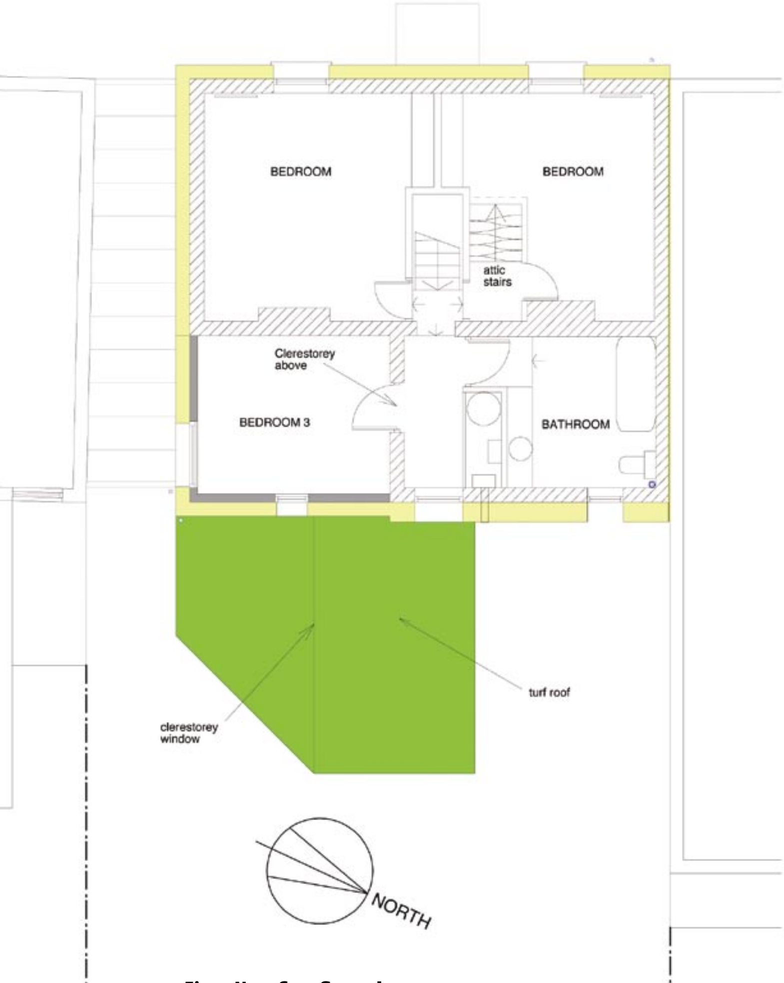


Fig 2. New first floor plan

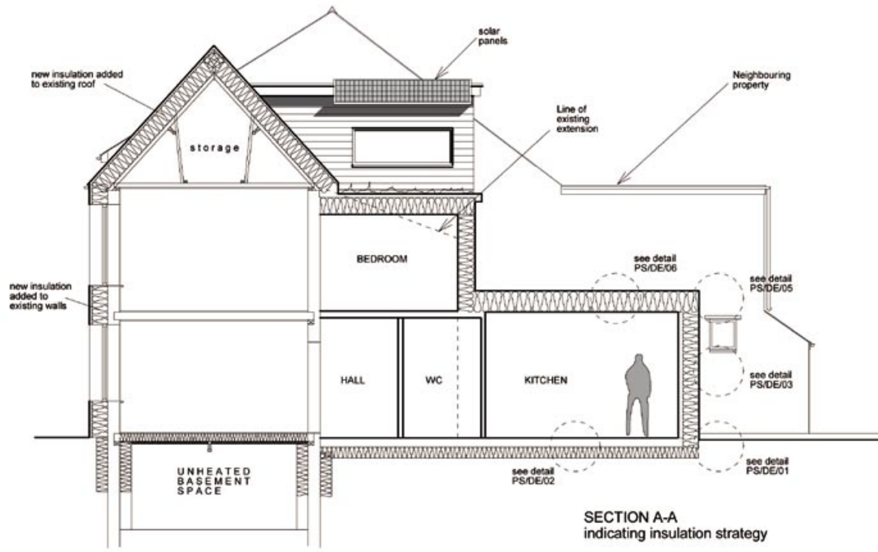
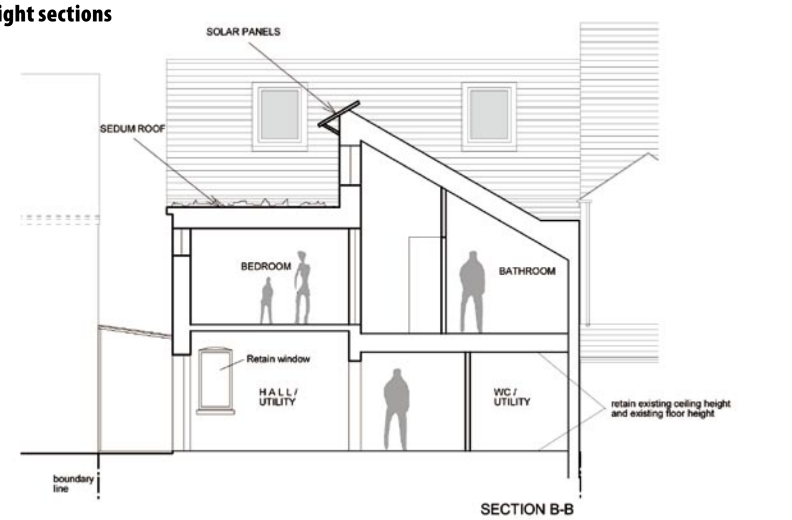


Fig 3. Height sections



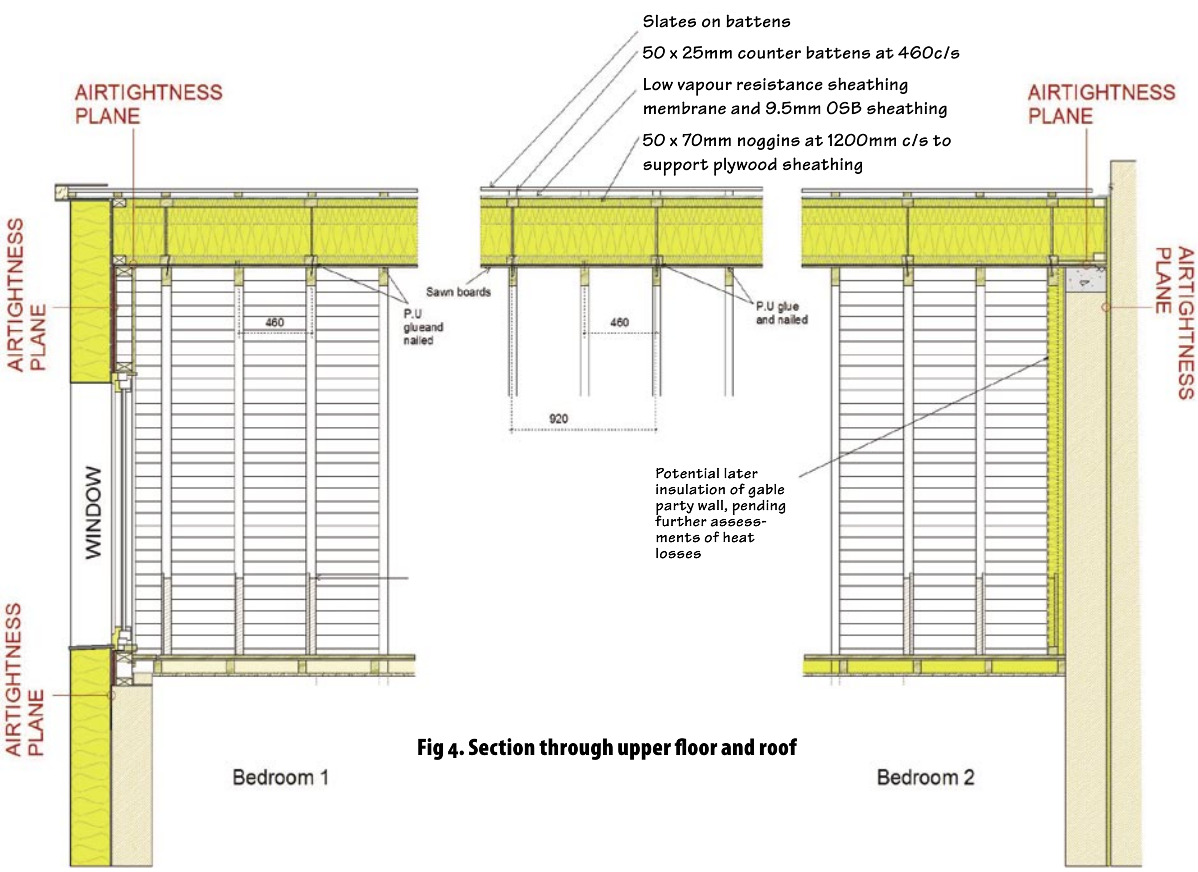


Fig 4. Section through upper floor and roof

New 400mm deep I beams at 920mm centres screwed via bottom flanges through air-vapour membrane (using polymer bitumen patches at screw positions) and 20mm t&g timber sheathing to connect I beams to alternate existing 75 x 55mm rafters. Fully filled with Crown Rafter Roll 32, mineral fibre batt.

Existing attic joists are 80 x 50mm nailed to sides of rafter feet. Both existing rafters and joists are in good condition and at 460mm centres.

Fix triangular plywood gussets one side of each joist. s.w. timber connection piece to underside of rafter to connect to plywood. Glued (PU) and nailed.

Glue and screw 2 no. layers of 12mm plywood to top face of attic joists, to create floor deck and reduce deflection of joists.

Plywood perimeter board to contain insula-tion and act as substrate for Permarock EPS external insulated wet render system.

councillors – with the Green Party councillor honestly questioning (and good for him!) whether the proposed 80% reductions in emissions being suggested were actually credible – we shall see.

Ideally a Passivhaus is orientated towards the south, as south facing windows can provide a net gain of useful heat during the winter, providing over a third of the total heat requirements of the building. East and west facing windows are less beneficial for heating. Normally a house on a north-south street has windows only on the east and west. Simmonds Mills also began early discussions with the planning department and the clients with their neighbours: the intention to incorporate large areas of new southerly facing windows has to take into account issues of overshading, night time light pollution and potential overlooking etc.

Post-planning, the design team later refined or modified elements of the design and construction prompted by modelling the designs with the Passivhaus Planning Package (PHPP) and the thermal modelling programme, Therm. It was satisfying to note that using simple 'rules of thumb' and the application of the guidance, and methodology developed for the CLP, resulted in the early design of an extension and a refurbishment strategy that, when modelled in PHPP, proved to need little modification to achieve an extremely good predicted energy performance. Hence, as no significant (in planning terms) modifications to the building form, or fenestration were required to improve energy performance, further complications with the neighbours and the planning department were avoided.

The design currently shows a space heat demand of $18kWh/m^2yr$ in PHPP, very close to the new build target specified by PHI of $15kWh/m^2yr$; however, there remain a few unaccounted for areas of construction giving rise to linear thermal bridging - which are near impossible to affordably 'thermally upgrade' (e.g. where chimney stacks pass through the suspended ground floor, or the vertical linear thermal bridge, where the thinner PU cavity insulation between no. 57 and a neighbour's gable wall meets the 250mm of external wall insulation). These junctions will be modelled, again using Therm, and may add a further 1 to $2kWh/m^2yr$ to this figure.

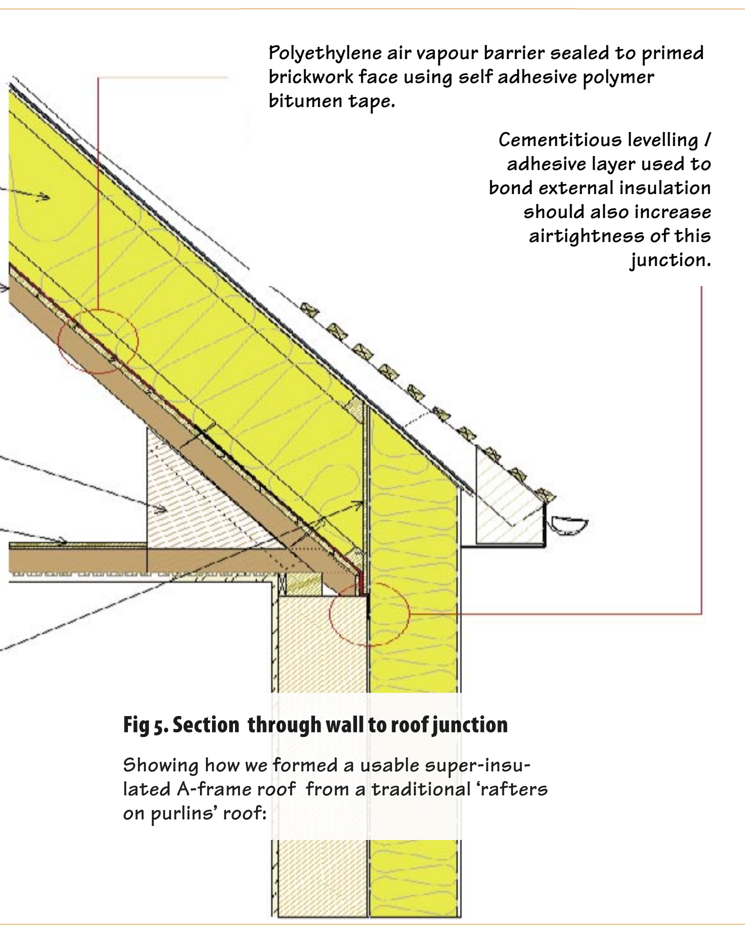


Fig 5. Section through wall to roof junction

Showing how we formed a usable super-insulated A-frame roof from a traditional 'rafters on purlins' roof:

The specific primary energy demand of $75kWh/m^2yr$ (a second requirement for CLP step 2/Passivhaus) should also be achievable in this project. However, in this case the predicted CO_2 emissions of the house would be similar to the AECB's 'silver' standard CO_2 target (around $22kg/CO_2/m^2yr$) - without the addition of a solar thermal system. In a new build Passivhaus standard could be achieved without solar thermal, but with the limitations posed by refurbishment of Grove Cottage, solar thermal was the most appropriate additional measure to compliment the more cost effective 'passive measures'. The building form itself, and the heating and hot water system is ready to accommodate $4m^2$ of solar thermal panels when the family can afford to fit them. A solar-ready hot water cylinder, and a dedicated area of roof (including pre-placed insulated solar pipe work to the cylinder) are part of this strategy. This will bring the CO_2 emissions down more in line with the requirements of CLP step two.

Summary of features and measures

Measures taken are described below, following the basic 'checklist' format set out in CLP Volume Three: The Energy Standards (performance version). Measures described in detail concentrate on the main roof refurbishment, insulating the existing brickwork walls and the external wall to ground floor junction.

Design to suit site

The new extension provided several opportunities to create south facing window openings to utilise passive solar gain. These generally had to be high level to avoid overlooking neighbours' gardens, but also provide significant daylight to rooms and do allow a significant contribution to space heating from passive solar gain.

A high level south facing platform, at 45 degrees off the horizontal, has been built to receive the $4m^2$ of solar thermal panels, which will be installed at a later date. The new hot water cylinder is 'solar ready', and the insulated solar pipes between it and the solar panel platform will be built in to avoid this work later impacting the air-vapour barrier, post construction.

Elemental U- values: (See Figs 1-7.)

Roofs: U-value = $0.09W/m^2K$
Walls: U-value = $0.12W/m^2K$

Externally insulated brick wall directly rendered

We took two approaches in respect of the walls. The first uses the Permarock EPS-Platinum insulated render

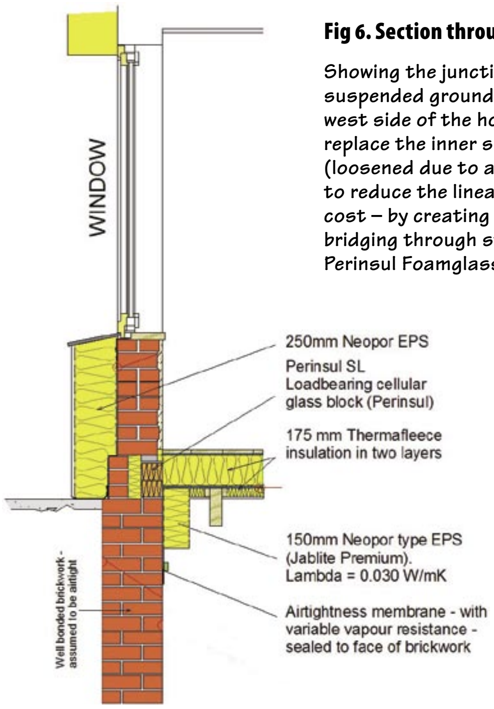


Fig 6. Section through basement/ground floor.

Showing the junction of the insulated basement ceiling (the suspended ground floor) with the external brick wall on the west side of the house (street side). Repair work needed to replace the inner skin of brickwork between old floor joists (loosened due to a rotted wall plate) afforded an opportunity to reduce the linear heat loss of this 10m junction at a low cost – by creating and insulating a cavity and reducing thermal bridging through structure by replacing the brickwork with Perinsul Foamglass blocks instead of bricks.

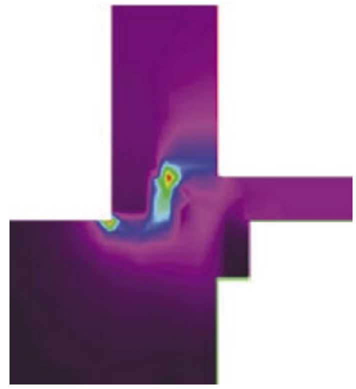


Fig 6a. Heat flux of basement insulation layout.

This shows an image of the heat flux resulting from this arrangement generated by Therm software. The calculated Psi_ext value (calculated as per PHPP conventions, in relation to external dimensions) is -0.019W/mK. This modelling exercise allowed the design of an affordable thermal bridgefree junction. This avoided the need to dig an external trench adjacent to the brick wall and place 250mm thick EPS insulation against the brickwork down to approximately 1200mm below ground – saving several hundreds of pounds.

system – adhesively bonded and mechanically fixed to masonry. The majority of the existing brickwork walls and all the new concrete blockwork walls of the extension were externally insulated using this system, which is based on a high performance expanded polystyrene (Neopor type, with a thermal conductivity of 0.030W/mK). The insulation is then directly rendered with a self coloured proprietary render. The U-value, without accounting for additional heat loss from the point repeating thermal bridges due to mechanical fixings, is 0.113W/m^{2}K, Heat losses from fixings can be very significant and must be accounted for.

Insulated render systems may include a series of mechanical fixings, which are normally of plastic and/or metal construction. Designers should be aware that all fixings that penetrate the insulation layer form a series of point repeating thermal bridges, directly analogous to the effect of metal cavity wall ties.

Once accounted for, metal fixings raise the wall U-value significantly. Plastic fixings have a lesser effect. Ideally we would have used the system with only adhesive-fixed slabs of insulation. This would give a thinner and more economical wall. Alternatively, the insulation boards can be fixed to the wall on a series of tracks which slot into grooves cut into the edges of the insulation boards. Whilst this approach results in the mechanical fixings being behind the insulation, the tracks hold the insulation away from the wall surface by a few mm and this may result in air movement behind the insulation - leading to heat losses.

The approach adopted at Grove Cottage employs full coverage adhesive bonding of the insulation boards, rather than the more common 'ribbon' of adhesive, so that there is no risk of air movement behind the insulation boards. Mechanical fixings are employed to provide additional support for the thick insulation boards whilst the adhesive cures.

As designers, we need to be aware that even adhesive-fixed systems may use a reduced number of mechanical fixings through the insulation in order to hold the insulation in place whilst the adhesive sets. So adhesive-fixed systems may not be entirely mechanical fixing-free, although, potentially fixings could, in some cases, be temporary and could be removed after the adhesive has fully cured.

However on the existing walls of the house we are unable to rely entirely on the adhesive, since the existing walls have been painted with masonry paint: failure in the adhesive bond between the masonry paint and the wall would result in the insulated render system becoming detached. Thus, a combination of adhesive bonding and mechanical fixing has been adopted. We are planning to use metal and plastic 'thermodowels' - manufactured in Germany and supplied in the UK by PermaRock. These have a μ-value (calculated using a 'finite element' method) no more than 0.002W/K. The fixings specified are plastic, with a steel pin running down the shaft of the fixing. If we were to leave these fixings flush with the external face of the insulation and on the basis of using four fixings per square metre, the U-value quoted above would become 0.121W/m^{2}K, and this would increase the specific space heating demand (as modelled by PHPP) by 1kWh/m^{2}yr taking it to 18kWh/m^{2}yr. However, these fixings can be

The builders

A small team of builders, led by Mike Neate of Eco-DC, was taken on to realize the plans. Eco-DC were employed on the basis of a day rate with between 3 to 4 builders on site each week - working towards a maximum budget of £100,000. Eco-DC also prepared the project schedule and cost plan. The project proceeded on the basis of an honest and trusting working relationship between architect/client and builders. The work was also carefully planned to allow the client and their young family to remain in the house during the project. Eco-DC are proving to be immensely capable in respect of both the quality of work required for a passivhaus level construction and also of the skills required to carry out extensive refurbishment with a family of five living in the property!

recessed into the insulation so that the heads of the fixings are 25mm behind the face of the insulation: a 25mm thick disk of polystyrene insulation is then placed over the fixing head so that the thermal losses through the fixing are reduced further. This method results in a U-value of 0.12W/m²K, but does not reduce the house's space heat demand below 18kWh/m²yr, suggesting metal/plastic fixings would need to be recessed further to make a significant difference.

Externally insulated brick wall using 'Larsen Truss' – timber clad

The second approach involved externally insulating some areas of existing brickwork using Larsen Trusses (350mm deep site built timber ladder trusses fixed to the brickwork, filled with insulation, sheathed and clad in sawn timber boards, see Fig 7). Using realistic percentages for the amount of thermal bridging created by the timber elements, a U-value of 0.12W/m²K can be safely used.

The east facing house wall structure changes from a (new) plywood sheathed studwork gable wall at high level to an existing solid brick wall lower down: the insulated Larsen Truss continues over both types of wall substrate. The timber frame wall has an air-vapour barrier on the face of the plywood sheathing, whereas the currently external face of the brick wall is parged with a cement based slurry to create an air-tight layer. Both areas of wall will be covered with 350mm of insulation contained within the timber Larsen Truss.

Floors

Three floor arrangements were used:

- floating floor on existing concrete slab: U-value 0.21W/m²K
- solid new insulated reinforced concrete raft (extension): U-value 0.13W/m²K
- suspended timber ground floor/basement ceiling: U-value 0.17W/m²K. (See Fig 6.), insulated with three layers of Thermafleece sheep's wool insulation and plasterboarded finish.

External doors

All doors are standard Internorm Edition fully glazed doors - with stainless steel spacers. Designers should be aware of the impact on the U-values of using laminated glass in windows and doors.

Windows - 0.9W/m²K

The window U-values are calculated from three elements; the glass centre-pane U-value, the frame U-value, and the glass-edge psi value, which depends on the type of spacer used. Here, using Internorm's Edition windows with stainless steel spacers, the glass U-value is 0.6W/m²K (or 0.7W/m²K when laminated glass is used), the frame U-value is 0.86W/m²K, and the glass edge psi value is 0.048W/mK. The actual U-value of each window is different depending on the relative areas of frame and glass – i.e. how big the window is – and they range from 0.75 to 1.0W/m²K.

PHPP also includes the installation psi value in the window U-value. This is the additional heat loss incurred as a result of the short heat path through the wall around the window frame. This psi value will be minimised by

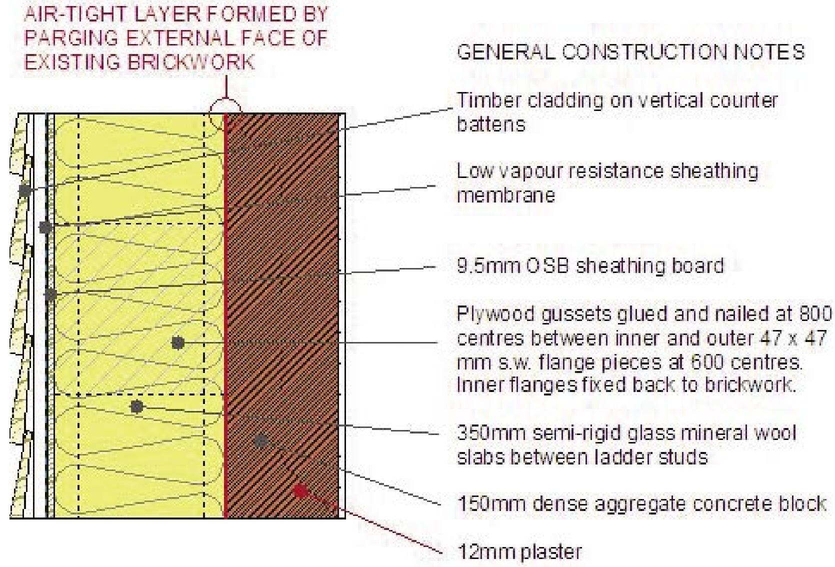


Fig 7. General construction detail for 'Larsen truss' external insulation method.

installing the external insulation to overlap the edge of the frame. Overall PHPP calculated the average U-value for the windows as-installed as 0.9W/m²K The final air permeability of the thermal envelope should be around 0.75m³/m²hr @ 50Pa. See Fig 7 for how this was addressed as we did not believe it was enough to rely on the existing plaster to provide an airtight seal to the house. In addition it was impossible to join the new airtightness and air-vapour membranes in the rebuilt roofs and new extension with the existing internal plaster layer. Existing ground floor and first floor joists also interrupt the internal plaster layer – meaning another strategy was required. By designating the external faces of the existing brickwork walls (see Fig 7) as the best strategy to position the air barrier and, where required, vapour control measures, a continuous airtightness 'plane' throughout the entire building was created. It is not possible in this article to elaborate on these measures, however it suffices to say that pending the all important air pressure tests, we feel that this strategy so far seems both practicable and promises success.

Party wall 0.4W/m²K

The neighbouring property to the north of Grove Cottage was built later – leaving a gap (approximately 25mm wide) between the gable walls of the two houses. This void has been filled by the builders with expanding polyurethane foam (ZODP). This insulates the wall (important at the external edges) and also should add significantly to the airtightness of this area of wall – remember, the designated airtightness zone is the external face of the brickwork of the house. If left uninsulated, this cavity would have continued to act as a 'thermal bypass' mechanism - allowing wind to pass between the buildings - carrying heat away from both houses in the process.

Once insulated this wall in effect acts thermally as a party wall between properties. PHPP discounts party walls for energy consumption as it assumes internal temperatures are the same in each house. However, in



refurbishment projects this is an unreliable assumption as the well insulated house will maintain a higher average temperature compared to the poorly insulated house - with thermostats set to the same temperature. In effect we have to assume some potential heat loss through this wall into the neighbouring house. This is not currently accounted for in our space heating demand of 18kW/m^{2}yr. With the U-value shown above and assuming an average temperature difference of 2 degrees between houses, the resulting heat loss is likely to be reasonably low – giving rise to another 1kW/m^{2}yr for the space heating demand.

Protection against overheating

Externally insulating the existing house - retaining the thermal mass of the masonry structure inside the insulation, mitigates against overheating. Relatively limited areas of south facing glazing (restricted due to the east west orientation of the existing house) also reduce the risk. PHPP predicts the risk of overheating at 2.5% meaning an internal temperature of 25 degrees centigrade will be exceeded for 2.5% of the year. Usually this is summer afternoons, and the Passivhaus standard accepts up to 10% of the year over 25 degrees,

Space heating system and hot water

The existing oversized radiators were retained, existing flow and return pipes are within the homes 'heated volume' and do not need to be insulated:

- Vaillant ecoTEC plus 415 non-system boiler (using natural gas)
- VRC430 weather compensator
- external pump: Grundfoss Alpha2 15-5 pump.

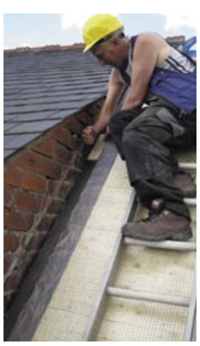
For the hot water, we installed a twin coil, solar domestic hot water unvented cylinder and all hot and cold pipe work, and valves are insulated with 40mm thick aluminium foil coated mineral fibre pipe insulation:

- 300L capacity with 50mm PU insulation and an additional 100mm of mineral fibre lagging added on site. This size cylinder, with a larger solar coil area of 1.62m^2, was chosen to improve the efficiency of the solar panels (when we install them).

Primary energy consumption strategy

The strategy is to work towards replacing domestic electrical equipment and white goods as the opportunities arise over time. However, we will be accounting for the performance of current appliances, when time permits finding out energy performance information. Currently owned appliances to be accounted for:

- fridge: Baumatic BFE 25655
- washing machine: AEG Oko-Lavamat 74630
- dishwasher: a recently bought ISE DW51
- electric tumble drier - to be replaced with 'MVHR serviced' clothes drying cupboard.



Ventilation and heat recovery

Ventilation is to be provided by a mechanical ventilation and extract system with heat recovery (MVHR). This form of whole house ventilation is necessary in such a well sealed house, and importantly the heat recovery is needed to meet the Passivhaus heating energy standard. The MVHR unit will reduce the family's CO_2 emissions and provide high internal air quality. We are interested to see how supplying the house with fresh air in this way, combined with the high levels of fabric insulation and airtightness, will limit external noise into the house (the system's ductwork includes sound attenuators). The system used is a Paul Thermos 200 – this is imported from Germany by the Green Building Store. It is designed to be extremely efficient: the unit is built from expanded polystyrene to prevent the thermal bridging you get with a metal case, and the heat exchanger itself is large to offer minimal resistance to airflow yet it should recover virtually all the heat from the outgoing extract air.

In the house air is extracted from the bathroom, utility, kitchen and upper hallway, via ducts to the MVHR unit. Air is supplied from the unit via more ducts to the living rooms and bedrooms. The ductwork to be used is Lindab rigid, galvanised steel ducting. Designing in the ductwork into an existing house has had its 'fun' moments, and required some significant design changes to create space requirements for the unit itself and also the correct relationship of the unit with the main intake and exhaust ducts through external walls. The opportunity for a new false first floor above an existing floor (to level existing floors between different parts of the house) allowed a neat hidden way of accommodating the main duct runs.

PassivHaus Planning Package (PHPP) explained

This is the software[1] for predicting energy consumption developed for Passivhaus design. Basically similar to SAP or NHER type programs, PHPP is optimised for the modelling of super-insulated buildings with mechanical ventilation systems. At this level of design the actual heating energy consumption is the small difference between total heat loss and the various heat gains in a building. Solar energy is usually the largest gain with a Passivhaus design and PHPP goes into some detail modelling the windows and their shading.

Why did we use it on this project?

The AECB's energy standards use the Passivhaus software, for both 'silver' and 'gold' standard as well as for the Passivhaus standard. Although a bit trickier to use than SAP, PHPP provides much better feedback on aspects such as passive solar design and heat recovery ventilation, as well as dealing carefully with thermal bridges and including the impact of thermal mass.

Using PHPP for refurbishments

There is no fundamental problem with using PHPP for modelling refurbishments, provided the house is designed for continuous mechanical ventilation. For a newbuild design normally all junctions e.g. wall/floor or wall/roof, are designed to be 'thermal bridge free'. For refurbishment this may not be possible, in particular wall to floor junctions are hard to deal with. For Grove Cottage we calculated the thermal bridge using Therm (not very straightforward), admittedly PHPP then allows for the entry of specific linear thermal bridges where they are above the Passivhaus standard level. For Grove Cottage we measured off drawings, entering wall, floor and roof dimensions, all according to the PHPP criteria, which are different to SAP. Basically all fabric dimensions are taken externally, effectively overestimating the heat loss area slightly, and the internal floor area is measured excluding internal walls, stairs and ducts etc.

One problem we did find is that PHPP carefully calculates the ground floor heat loss characteristics, depending on whether the floor is suspended, ground bearing or over a cellar. Here we had three different floor constructions, two ground bearing and one over a cellar – and have to accept that the result will be slightly inaccurate as a result (there is about 5% difference between the heating demand calculated with the floor all ground bearing compared with all of the floor above a cellar).

Windows and shading

In a Passivhaus design the heat input from solar gain is typically around a third of the gross heat loss – about the same as the input from the actual heating system. So PHPP requires window data in some detail.

First you identify the frame type and glass type. There are a range of pre-set figures for frame U-value and section widths for typical window frames, and for a number of Passivhaus window systems. These are matched with a glazing unit, with figures for both U-value and g-value (how much solar heat energy is admitted by the glass). There is also a figure for glass edge psi value, which depends on the type of spacer used, and the installation psi value, for which there is a list of possible options depending on how well integrated the window frame is with the wall insulation.

These figures seem like a lot of detail, but they are available from window manufacturers, and varying any of them makes a noticeable difference to the final heating demand. For instance, the U-value of a window frame may not seem crucial, but then timber window frame may comprise 30% of the window area, and with, for example, 30% of a wall glazed, the frame will be 10% of the total. An ordinary timber frame, U-value 1.6 say, will be responsible for the about the same heat loss as the entire opaque wall insulated to a U-value of 0.15.

Then the actual window dimensions are entered window by window, with the appropriate frame section and glazing selected. Windows have to be divided up into glazing units, as the frame area and edge psi are calculated from the window dimensions. Note that height and width have to be correct, not just area, as this has a bearing on solar gain. Orientation is added here too.

For Grove Cottage we started with the manufacturer's data listed in PHPP for the windows (made by Internorm) and put in a first stab at the proposed window sizes. These can later by adjusted to see how sensitive the design is to variation, and have now been corrected to the window sizes as ordered. Also the frame specifications have been altered as the window, now available in the UK, seems to be a different specification from the one listed in PHPP.

After window entry, shading needs to be considered. First distant objects are considered, e.g. the ridge of the house across the street. This had little effect on most windows but significant impact on a few. Then each window also needs measurements for the reveal depth and width of frame to the reveal edge, and ditto for the overhang (usually the same as the reveal). These determine the shading angles around the window, which make an appreciable difference to the solar gain and hence the final figure for heating energy.

Ventilation

PHPP is designed for mechanical ventilation only, primarily heat recovery ventilation, but can also deal with continuous extract ventilation. The program has a simple ventilation rate estimator, based on the number of people assumed in the building, the numbers of bathrooms, kitchen etc, and a backstop minimum rate of 0.3 air changes per hour. Generally a range of ventilation rates would be used in practice – i.e. boost for bathtime and setback for overnight, these can be worked out and the average derived – in Passivhaus design it normally comes between 0.3 and 0.4 air changes per hour.

Infiltration is based on a pressure test figure in terms of air changes per hour at 50Pa, i.e. the measured leakage rate divided by the volume of the building. This is different from the permeability figure used in UK building regulations where the leakage rate is divided by the external surface area of the building. A pressure test contractor will be able to derive both figures from his airtest results. For Grove Cottage we have a target of 1 air change per hour, which for this building works out at $0.75m^3/(m^2h)$ which is challenging for newbuild let alone a refurb, but does not quite reach the German Passivhaus standard of 0.6 air changes per hour.

MVHR units are selected from a list of Passivhaus tested units, with figures for heat exchanger efficiency and fan power. Awkwardly the efficiency figures are different from the SAP appendix Q ones (and of course less optimistic than the ones in the sales literature). The reason is that PHPP takes the efficiency of heat recovery from the point of view of the temperature of the air,

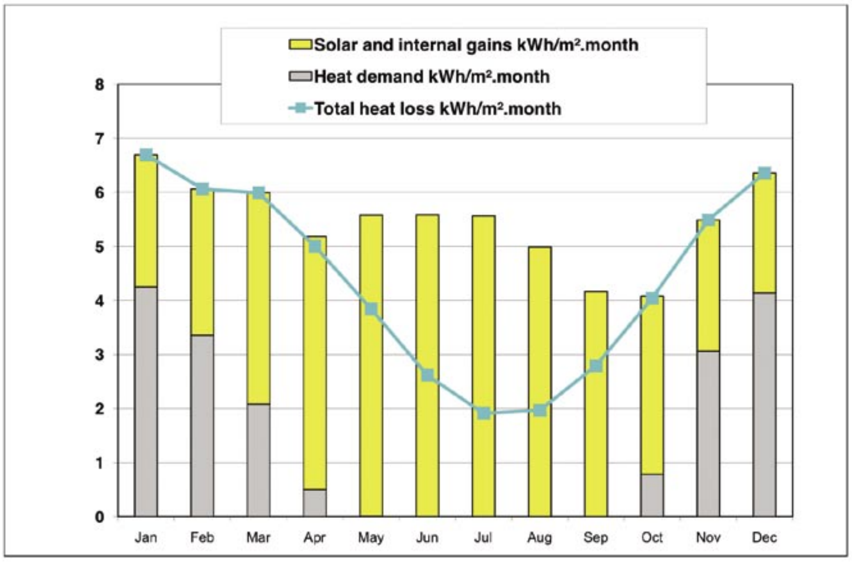


Fig 8. Gains, demand and heat losses as predicted by PHPP.

leaving the building compared with the air coming in – i.e. how much heat is lost overall. Other efficiency measures look at the temperature of the supply air to the room and see how much heat has been transferred. These are not the same, as heat transferred from the room to the MVHR unit (which has a low average internal temperature) shows up as an improvement in efficiency in the second approach and a reduction in efficiency in the PHPP approach.

Then the efficiency of the MVHR unit is adjusted to take into account heat loss through the ducts transferring cold air between the MVHR unit and outside. Again this seems like an intrusive amount of detail, but the impact of long or poorly insulated ducts on effective efficiency is very large, and as the total heat recovered exceeds that needed from the heating system in a Passivhaus, the detail is very significant.

Results

The blue line in Fig 8 shows the total predicted heat loss and the yellow bar shows the predicted contribution from solar and internal gains, with the heating, shown in grey, making up the difference. The figures for heating – the grey bar – for each month are added up across the year. Here the total is around 18kWh/m^2 - not quite to Passivhaus standard, but very close.

Breakdown into various elements of heat loss

Here walls and windows are the main heat-leaks. However it is important to consider the solar input when looking at the impact of the windows – in this case useful solar gain turns out to be 70% of window heat loss. With a Passivhaus newbuild, rather than a refurbishment it is reasonable to expect to get the solar gain to equal the window heat loss by considering the building orientation at the outset and concentrating the windows on the south facade.

Heating systems

A lot of people associate Passivhaus design with heating via the ventilation air – or ‘no heating system’. However, you can just use radiators. This doesn’t affect the Passivhaus standard – it is simply set so that you could heat via the ventilation air if you wanted to.

In Grove Cottage we are using the existing plain old radiators – the cheapest and simplest approach. Heating via the ventilation air would be a bit touch and go – at just outside the Passivhaus standard the total amount of heat the ventilation air can carry without being too hot is just equal to the design heat load. However, this gives no margin for any construction faults, or even a particularly cold winter. Also it is only an average, so some rooms would need to be considered carefully to check that enough warm air is coming in to keep the room up to temperature. In the case of Grove Cottage the kitchen would have been a problem – you extract air from kitchens, and the make-up coming from other rooms would be around 20°C, not the 40-50°C needed to provide heating.

Dissemination

The project will be a case study for:

- the AECB CarbonLite Programme (CLP) - a case study will be written by independent experts. Dissemination and promotion
- the European Passive House Network Project (PASS-NET). Dissemination, promotion and public open days
- The New Home Super Home Project (NHSH). Dissemination, promotion and public open days. Currently there are 25 houses in the Superhomes Network (being run by the Sustainable Energy Academy - www.s-ea.org.uk) and the National Energy Foundation
- two Leeds Metropolitan University projects working in conjunction with the AECB: The ‘Sustainable Housing Construction Learning Zone’ and the ‘Low Carbon Housing Learning Zone’ (Centre for the Built Environment - Buildings and Sustainability Group)
- the Passivhaus Institut. Dissemination and public open days (in conjunction with PASS-NET project).

We expect this project to stand out for both its rigorous design and its build quality - combined with a modest construction budget. We will of course be measuring its ongoing energy performance via utility bills.

Andrew Simmonds of Simmonds Mills Architects and Alan Clarke, Energy and Services Design

Refs:

1. PHPP is available in the UK from www.carbonlite.org.uk

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- Knauf Insulation (Crown Rafter Roll 32 for all roof insulation and DriTherm Cavity Slab 37 for the insulated Larsen Truss wall). Knauf are also funding the air pressure testing and a full case study for the project - to be written by independent experts.
- Internorm windows UK.
- Second Nature - Thermafleece insulation.
- East Midlands Insulation – pipe insulation.
- Permarock - external rendered insulation system.
- Ecology Building Society - C-Change mortgage.
- Vencil Resil (Jablite insulation).
- Green Building Store (MVHR).

Andy Simmonds is an architectural designer and builder and a partner in Simmonds-Mills, a practice which specialises in ecological design. Through his practice’s long-standing membership of the AECB, he has developed working relationships with the leading designers and tradespeople in the field of ecological building. Being both designer and builder, he has gained practical insights into the viability of ecological techniques, and has taken up on-the-job training of other trades. Andy is also currently part time CEO of the AECB.

Alan Clarke is an Energy Consultant and Building Services Engineer, who works exclusively on low-energy buildings. He provides design advice to architects and developers to produce low energy buildings, focusing on built form, thermal performance and daylight. Alan is an experienced user of PHPP and is currently working on a number of Passivhaus projects, including housing, offices and schools.