Lancaster Cohousing Project

A Certified Passivhaus / Code For Sustainable Homes (Level 6) And Life Time Homes, Affordable Community Housing Project.

Design Philosophy & Innovation Report For The Passive House Trust Awards 2013

Statement of Achievement Of Other Sustainability Credentials

THE QUEENS AWARD FOR SUSTAINABLE DEVELOPMENT

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Lancaster Co-housing Project

Lancaster Co-housing Project is a certified Passivhaus/CSH level 6 and Lifetime Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects. Work is just about to start on site on what will be the first certified Passivhaus Co-housing project in the UK, and, we believe, the second largest Passivhaus certified development, with forty one individual households, ranging from one bed flats to three bed family houses, thirty five of which are within the co-housing scheme with shared community facilities. Over the next eighteen months we will follow the project through the construction phase with a series of in depth technical articles through to completion. Jon Sear and Andrew Yeats report ...

Many people are taking action at a household level to cut their carbon emissions. Many more are working to change the policies that determine the carbon footprint of their city, town or village. In Halton, three miles from Lancaster City Centre, Lancaster Co-housing is creating a new eco-community of 35 homes; small enough for everyone to know each other, yet big enough not to be claustrophobic. Crucially the size allows us to do a lot towards reducing our carbon footprint that would not be possible for a single family, or a scattered group of households.

The project has all the typical features of co-housing, a way of living pioneered in Denmark but now growing in many countries. We will be building small houses with extensive common facilities. We have designed the site to encourage a strong sense of community. Residents have been involved in the design process and will manage the site when we move in. Obviously involvement has varied depending on when people have joined. The design has grown to 35 households over the course of several years. We are an intergenerational community already, including ten children aged under 10.

The group formed in 2006 and set down a clear vision, including a commitment to being a cutting edge example of sustainable design and living. We were also very clear about looking for a site with easy access to amenities without a car, in Lancaster, where all the founding members lived and worked. The frustrating process of trying to buy a development site took years, but the land we finally purchased in July 2009, on the edge of the village of Halton, was worth the wait...

The six acre site, Forge Bank, is right next to the River Lune, but the buildings will be above the predicted 1 in 1000 year flood level. All the homes will have south facing views down to the river; perfect for passive solar gain and for solar panels (except under the trees). Whilst it's further from town than some of us ideally wanted, there is a flat, traffic free cycle path straight into Lancaster railway station, and many other destinations. We are redeveloping a derelict engineering works, which has become a real eyesore in an otherwise beautiful environment, as workshops and offices. We have a small woodland and some space for food growing.

The householders that had joined the scheme spent several years developing the designs with the project architects, Andrew Yeats, Lucy Nelson & Vincent Fierkens

Above: the artist's impression.

Below: the plans for the project have been developed with the involvment of community members at every stage. Many of the people who have joined the project have been pioneers in some aspect of ecological or community living, and they expect to learn a huge amount from living together, significantly reducing their collective environmental impact. The community also want to share what they have learnt with others. There are plans to create a visitor centre in a building by the river. When members join the project they each agree to open their house up once a year to visitors to come and look around.

of Eco Arc, obtaining planning permission and building regulations approval. Now we are working with the specialist design team lead by Eco Arc, including Alan Clarke, Nick Grant and Peter Warm on the Passivhaus design aspects, Eric Parks on the Code for Sustainable Homes & Lifetime Homes aspects, Gifford on the civil and structural designs and David Fotheringham on quantity surveying and project management. Local contractors, Whittle Construction, were selected over a year ago under an NEC two stage partnering contract to be part of the design team and ensure build-ability within a guaranteed maximum price. We made links with the Parish Council and local community association as soon as we bought the site and have formed a partnership, Halton Carbon Positive! which successfully applied to DECC for Low Carbon Communities Challenge funding.

The homes have been designed to meet the PassivHaus standard, this approach has three main strands:

- Minimise heat loss – super insulation, triple glazing, compact built form.
- Minimise ventilation heat loss – heat recovery ventilation and airtight construction.
- Optimise solar gain for winter heat.
- Energy use for heating will be less than 15kWh/m^2 per year, achieved through very careful attention to airtightness and thermal bridging, and the use of an efficient ventilation system with heat recovery.

We plan to supply hot water and the single radiator required in each house through a woodchip district heating system, pre-heated using solar thermal panels. The fuel will come from managed woodlands in Lancashire and Cumbria.

We have prioritised reducing the energy that will be used in the buildings each year because this is by far the most significant component of their environmental impact. We have also given a high priority to durability, rejecting the standard assumption that new buildings should be designed only to last 60 years. This has a big impact on embodied energy, which needs to be considered over the lifetime of the buildings. The project includes shared facilities, such as offices, guest bedrooms and laundry facilities, enabling many households to choose a smaller home than they would otherwise want. This reduces both energy in use and embodied energy.

There is also a 100 year old stone mill building, which was previously scheduled for demolition but that we will be renovating this to provide new office and workshop space. Residents will be offered workspace at favourable rates to reduce the amount of commuting. Rather than making modest improvements to the insulation throughout this building we intend to put all the funds currently available into a huge improvement in the insulation and airtightness of the roof, from which over a third of all heat is currently lost. At the same time we will carefully seal up the holes in the walls which have accumulated from 100 years of different industrial uses. This has no net cost as it means we can install a smaller, cheaper biomass boiler. Having got the most disruptive insulation work out of the way we will be able to use income from renting the workspace to upgrade walls, doors and windows, until the building is better insulated than one built in 2010, despite its age.

Co-housing developments typically keep cars to the edge of the site, and ours is no exception. As transport is a significant proportion of most households' carbon footprint we have an ambitious residential travel plan. The village has a good bus service, running late into the evening, but the nearest bus stop is five minutes' walk away, so cycling will be the quickest option for getting into town. We have a lot of cycle parking space to help make this as easy and attractive as possible.

For those few stubborn journeys that can only be made by car, we are setting up a car share scheme, with about one car per three households. Initially the scheme will be run using members' existing private cars, but these should be replaced by electric vehicles over time. Not needing a parking space for every house gives us more green space.

Many of the people who have joined the project have been pioneers in some aspect of ecological or community living, and we expect to learn a huge amount from living together, significantly reducing our collective environmental impact. We also want to share what we have learnt with others. We have plans to create a visitor centre in a building by the river. When members join the project they each agree to open their house up once a year to visitors to come and look around.

We plan to grow some food but we will need to buy most of it. Buying in bulk will reduce packaging and help us seek out seasonal foods, and we hope to set up a community supported agriculture scheme with a local organic farmer. Our shared meals in the common house will be vegan and vegetarian. Most of us do eat meat, and still will at home, but our commitment should mean that there is always a healthy meal available for everyone and will lead to a much lower carbon diet than most of us currently achieve.

Electricity will be supplied by photovoltaic panels on the south facing roofs and a 160kW hydro turbine in the River Lune. This will easily make the project zero carbon, but it hasn't stopped us doing everything possible to minimise demand. Not everyone has access to a good location for a hydro or wind turbine so the more electricity we can export from our site, the better.

In the next magazine article we will discuss in detail the deployment of the Passivhaus design principles in the project and review the ground work, foundation and floor slab construction details as the houses emerge out of the ground.

Jon Sear and Andrew Yeats

More information can be found at WWW.LANCASTERCOHOUSING.ORG.UK

Credits

Client: Lancaster Co-housing represented by Jon Sear

Architect: Andrew Yeats & Vincent Fierkens of Eco Arc Ecological Architecture Practice

Project manager and quantity surveyor: David Fotheringham of Turner and Holman

Structural civil engineer: Gary Willis of Gifford

M&E engineer Passivhaus designers: Alan Clark / Nick Grant

Passivhaus certifier: Peter Warm

CSH &and Life Time Homes: Eric Parks

Main contractor: Graham Bath of Whittle Construction.

Jon Sear is a freelance project manager, environmental consultant, and a future resident at Forge Bank. Jon was a co-founder of the Lancaster Cohousing project and has worked for the last year as the client representative/ project manager within the participatory design team. JON@LANCASTERCOHOUSING.ORG.UK

Andrew Yeats of Eco Arc Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for cohousing, having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years. ECOARC@ECOARC.CO.UK

Lancaster co-housing project

(part 2)

Lancaster co-housing project is a certified Passivhaus/ CSH level 6 and Life Time Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects. Alan Clarke and Andrew Yeats report.

Work has now started on site on the largest certified Passivhaus co-housing project in the UK with forty one individual households, ranging from one bed flats to three bed family houses, along with shared community facilities. In this part two article we will cover works in progress on site with regard the foundation/ground slab detail and an overview of how we have designed the project to the Passivhaus standard.

We started work on site in late August and the house foundations and dwarf walls up to DPC are now emerging out of the ground. As the site was a steeply sloping brown field site, we have undertaken extensive demolition works to take down the existing engineering buildings, plus remediation and slope stabilisation site works. All the spoil, stone and brick arisings have been retained on site and will be reused in the landscape design and for forming reclaimed stone/brick faced gabion basket retain walls to hold back the 1 in 2 site slope down to the river.

Post demolition works the house building platforms were proof rolled and compacted at the appropriate level, (approx 600mm above the projected long term flood level). Traditional strip foundations were dug and ground bearing slabs poured using ground granulated blast furnace Slag (GGBS) as a cement substitute in the concrete. We wanted to use recycled aggregate but could not source a local approved supplier. GGBS and recycled aggregate will be used elsewhere in the site concrete works.

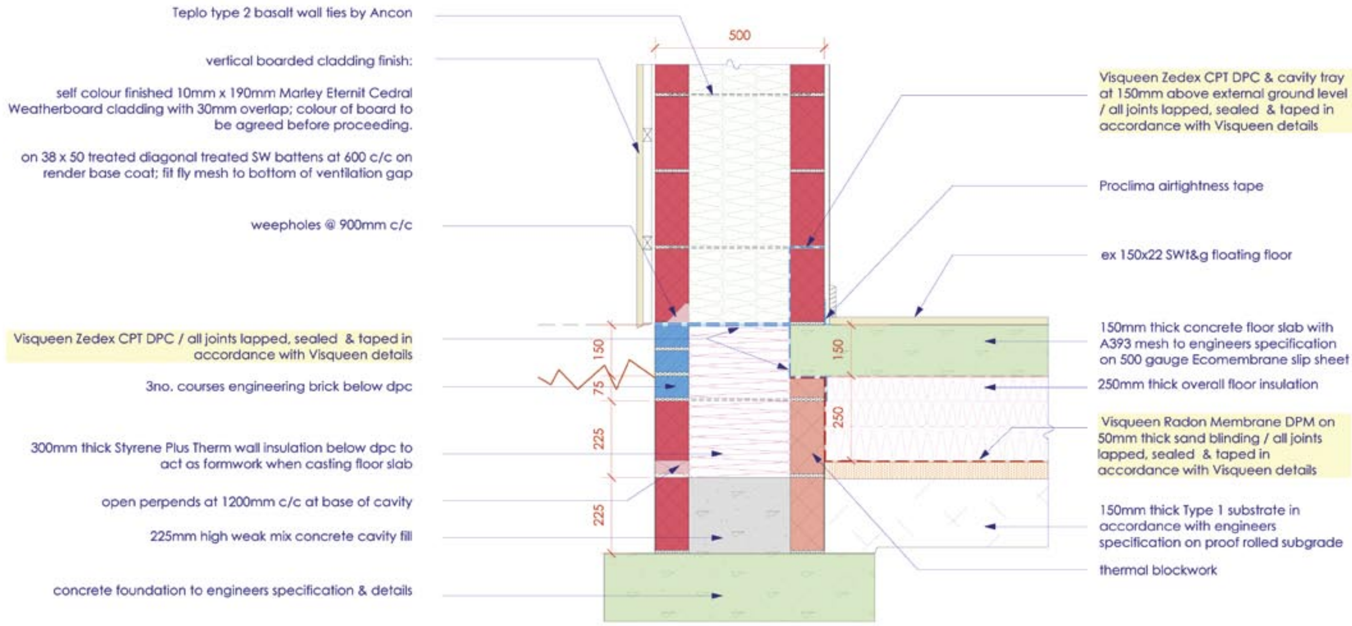
The key details to note that enhance this conventional cost effective detail up to Passivhaus standard (see Fig 1) include the following:

- 250mm below slab EPS insulation to achieve a target U-value of 0.15.
- Concrete slab is poured across the top of the wall inner leaf to form an air tight seal at this vulnerable junction. We used full-fill cavity insulation as shuttering for the poured ground slab concrete floor. (Traditionally this junction can be air leaky due to shrinkage cracking between the wall and floor.)
- Ground bearing concrete slab is over sized and reinforced to support load bearing internal walls, avoiding cold bridging normally associated with internal strip foundation dwarf walls penetrating the 250mm below slab insulation layer.
- Thermal blockwork inner leaf built below concrete slab level to the top of strip foundation to reduce the cold bridge impact of this junction to a sensible minimum.
- 300mm closed cell EPS fulfil cavity wall insulation taken down 450mm below DPC level, again to reduce cold bridge impact to a sensible minimum. (see Fig 2 Therm diagram on next page).
- Wet internal wall plaster (air tightness barrier) taken right down to the top of the concrete slab, with air tight tape to the back of the skirting board as a bullet proof air tight seal detail).
- All service pop ups for water, electric, district heating service pipes and outgoing waste drainage pipes are taken through the slab below ground (rather than through the wall) and sealed at top of slab level with grommets.

The Passivhaus standard is a successful European ultra-low energy standard for buildings. Passivhaus buildings use only a fraction of the energy for heating than those built to the standards required by current Building Regulations, and deliver low carbon solutions without

300mm closed cell EPS full-fill cavity wall insulation below DPC level, ready to be used as shuttering for the poured concrete floor.

Fig 1. Ground floor to wall junction detail



One of the requirements of Passivhaus design is 'thermal bridge free' details. The heat loss through poorly designed junctions can exceed that through the actual floor, roof and walls when they are insulated to Passivhaus levels. Here is the wall/floor junction developed for this project. The problem we have is the internal leaf of the blockwork wall cutting through the thick layer of insulation that runs under the slab and up the cavity. Ideally the insulation forms a continuous blanket around the building, but at this point we do have to hold the houses up as well.

The solution illustrated here is the use of insulating concrete blocks forming the lower courses of the internal leaf of the wall, specifically where the wall crosses the insulation. Although aerated blocks aren't wonderful insulators, the heat has to pass through at least 250mm of block, which adds up to a useful amount of thermal resistance. An expensive lower conductivity, but thinner 'thermal break' element may in fact perform worse than this if the rest of the wall is dense concrete.

The Therm analysis provides an accurate prediction of the heat loss through the junction using detailed numerical analysis to 'solve' the steady state of heat loss and temperature throughout the construction. Hence the "isotherms" of equal temperature on the diagram. Using the results of the analysis we can calculate the thermal bridge factor in terms of watts/m/K and add this in to the estimate of the total heat loss in PHPP.

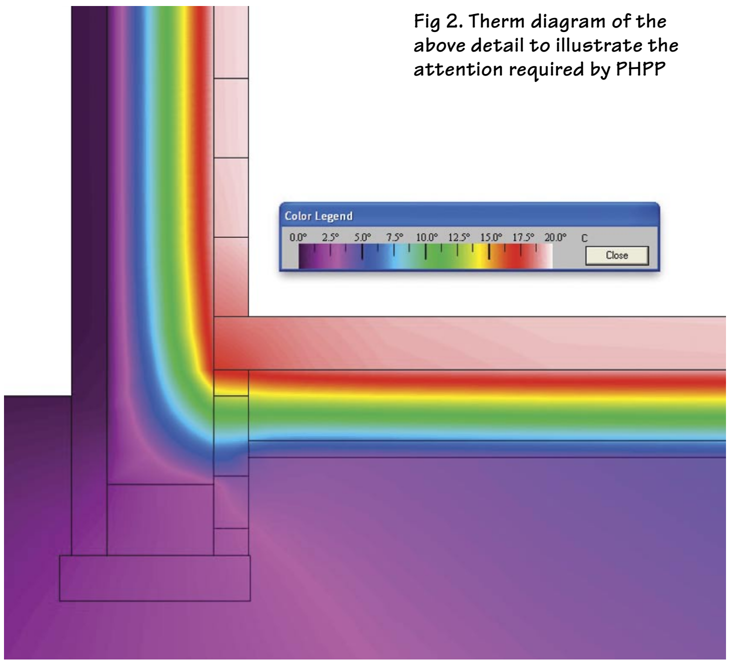


Fig 2. Therm diagram of the above detail to illustrate the attention required by PHPP

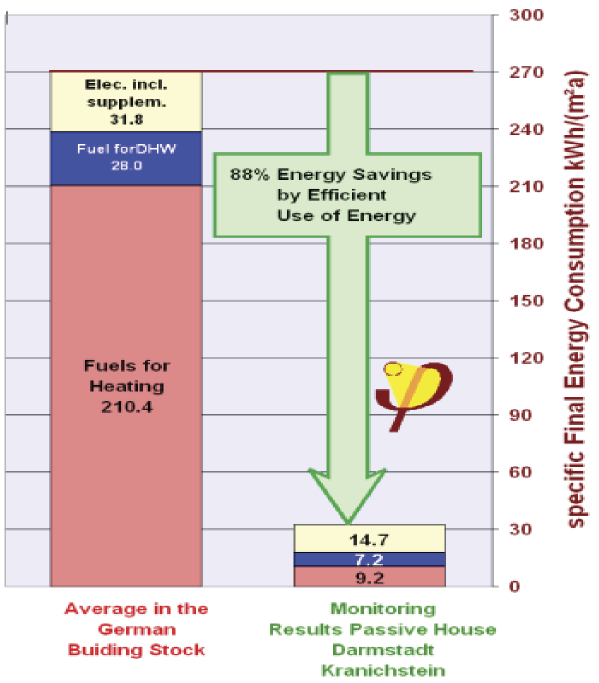
needing renewable energy. The Passivhaus approach has three main strands:

- Minimise heat loss – super insulation, triple glazing, compact built form.
- Minimise ventilation heat loss – heat recovery ventilation and airtight construction.
- Optimise solar gain for winter heat.

These factors combine to deliver a heating demand that can be met with a minimal heating system – though it is recognised by many that to design a house that needs no heating at all is not economic. So for the homes in the co-housing scheme the heating system is a radiator in the living space and a towel rail in the bathroom, with a total heat output below 1kW for the whole house. The Passivhaus heating demand must be the same whatever fuel is used. This recognises that renewable energy is, in practice, in limited supply and ensures the houses are cheap to heat whatever the fuel source.

As well as very low heating bills, Passivhaus offers comfort and a healthy indoor environment. Attention to detail in design and construction ensures no draughts or cold spots wherever you are in the house. Heat recovery ventilation uses low power fans to provide ample fresh air day and night, warmed to room temperature by a heat exchanger transferring the heat from the exhaust air from kitchen and bathrooms. >>

Fig 3. This shows the results of monitored energy consumption in Germany where Passivhaus originated. Energy consumption of average UK stock is very similar to the German figure.



The standard

Passivhaus is a rigorous energy standard; energy performance must be demonstrated through the use of the Passivhaus energy modelling software, PHPP, which is specifically designed to model ultra-low energy buildings. This is backed up by air leakage tests on every house and commissioning records of the heat recovery ventilation. The standard requires a predicted heating demand of 15kWh/m².a over the usable floor area, and for the local climate. Average for UK stock is around 200kWh/m².a and new-build ranges from 50-100kWh/m².a.

We have developed the design of the co-housing development using PHPP from the outset and this has directed the design of the houses as compact terraces, all facing south. This form has minimised the heat loss from the individual houses and enabled each house to receive its share of winter sunshine. The analysis of the planning design shows that all terraces achieve the Passivhaus standard. The insulation levels needed to do this can be met with traditional cavity wall construction combined with triple glazed windows and airtightness provided by wet plaster and the roof vapour control layer. The specification to achieve this is as follows:

Element	U-value	Insulation
Floor	0.15	250mm EPS under floor
Wall	0.12	300mm full fill masonry cavity
Roof	0.11	400mm in loft
Windows	0.89	Triple glazed low-e argon fill

The airtightness standard of 0.6ach@50Pa is a requirement of Passivhaus. The reasons are to ensure draught-free comfort, protect the building fabric from condensation (by preventing leakage of humid air through cracks into the construction), and to ensure that the efficiency of the heat recovery ventilation isn't bypassed by leakage ventilation. Although this is less than a tenth of the requirement for new UK dwellings the design team are familiar with the design requirements of the standard and have already achieved airtightness close to 0.3ach in new-build.

Where Passivhaus differs from UK Building Regulations and CSH is the requirement for an absolute level of energy consumption instead of improvement over a more basic specification. Therefore the pair of 2 bed houses (36 & 37) would not meet the Passivhaus standard with the same construction as the terraces, owing to their higher surface area per house. We are therefore upgrading the specification on these houses with more expensive lower conductivity wall insulation to ensure they meet the standard too.

Fig 4. Results of preliminary analysis of PHPP (note here a terrace of 5 houses is analysed as a single thermal unit).

Specific Demands with Reference to the Treated Floor Area

	Applied:	Monthly Method	PH Certificate:	Fulfilled?
Treated Floor Area:	342.6	m²		
Specific Space Heat Demand:	15	kWh/(m²a)	15 kWh/(m²a)	Yes
Pressurization Test Result:	0.6	h⁻¹	0.6 h⁻¹	Yes
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):		kWh/(m²a)	120 kWh/(m²a)	
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):		kWh/(m²a)		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:		kWh/(m²a)		
Heating Load:	11	W/m²		
Frequency of Overheating:	0	%	over 25 °C	
Specific Useful Cooling Energy Demand:		kWh/(m²a)	15 kWh/(m²a)	
Cooling Load:	7	W/m²		

Heat source

The heating requirements of each house are too low to need a conventional boiler, so the houses are served by a district heating system which also heats domestic hot water. The primary heat source is the wood chip boiler proposed for the mill, combined with solar thermal panels mounted on the mill roof. This offers economies of scale in that only one pump and control system is needed for the solar panels rather than 30. Heat losses from district heating pipework can be surprisingly significant for what is widely considered to be an energy efficient approach. This is particularly the case when compared to the energy demand of a home built to Passivhaus standard. We are therefore using the best pre-insulated pipework we could source. Significant effort has also been put into assessing diversity of demand, as this allows smaller pipe sizes to be specified, again reducing heat loss. The wood chip supply contract will specify chip from local woodlands, reflecting sustainability concerns. Gas backup will be provided at the mill boiler room as maintenance back up for the biomass boiler.

Alan Clarke and Andrew Yeats

Project team

Client: Lancaster Co-housing represented by Jon Sear as client project manager

Architects and lead design consultants: Andrew Yeats, Vincent Fierkens & Lucy Nelson of Eco Arc Ecological Architecture Practice

Project manager and quantity surveyor: David Fotheringham of Turner and Holman

Structural civil engineer: David Tasker & Gary Willis of Gifford / Ramboll

M&E engineer & certified Passivhaus designers: Alan Clarke / Nick Grant

District heating system designer: Steve Pettit and Rob Clegg of Pettit Singleton Associates

Passivhaus certifier: Peter Warm

CSH & Life Time Homes consultant: Eric Parks

Main contractor: Graham Bath & Charles Whittle of Whittle Construction.

Alan Clarke is an energy and building services engineer specialising in Passivhaus design, building on long experience of low energy and ecological construction. He works with architects on a range of housing, school and office projects, new build and retrofit. He is also a developer and teacher of the Warm Passivhaus Designer Course. In his guise of building physicist he tends to ignore the traditional services engineer's role of designing services for whatever the architect has designed, and instead sees the building itself as the primary provider of thermal comfort, with just a simple heating system to finish the job.

Andrew Yeats of Eco Arc Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for cohousing, having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years. ecoarc@ecoarc.co.uk

Lancaster co-housing project

(part 3)

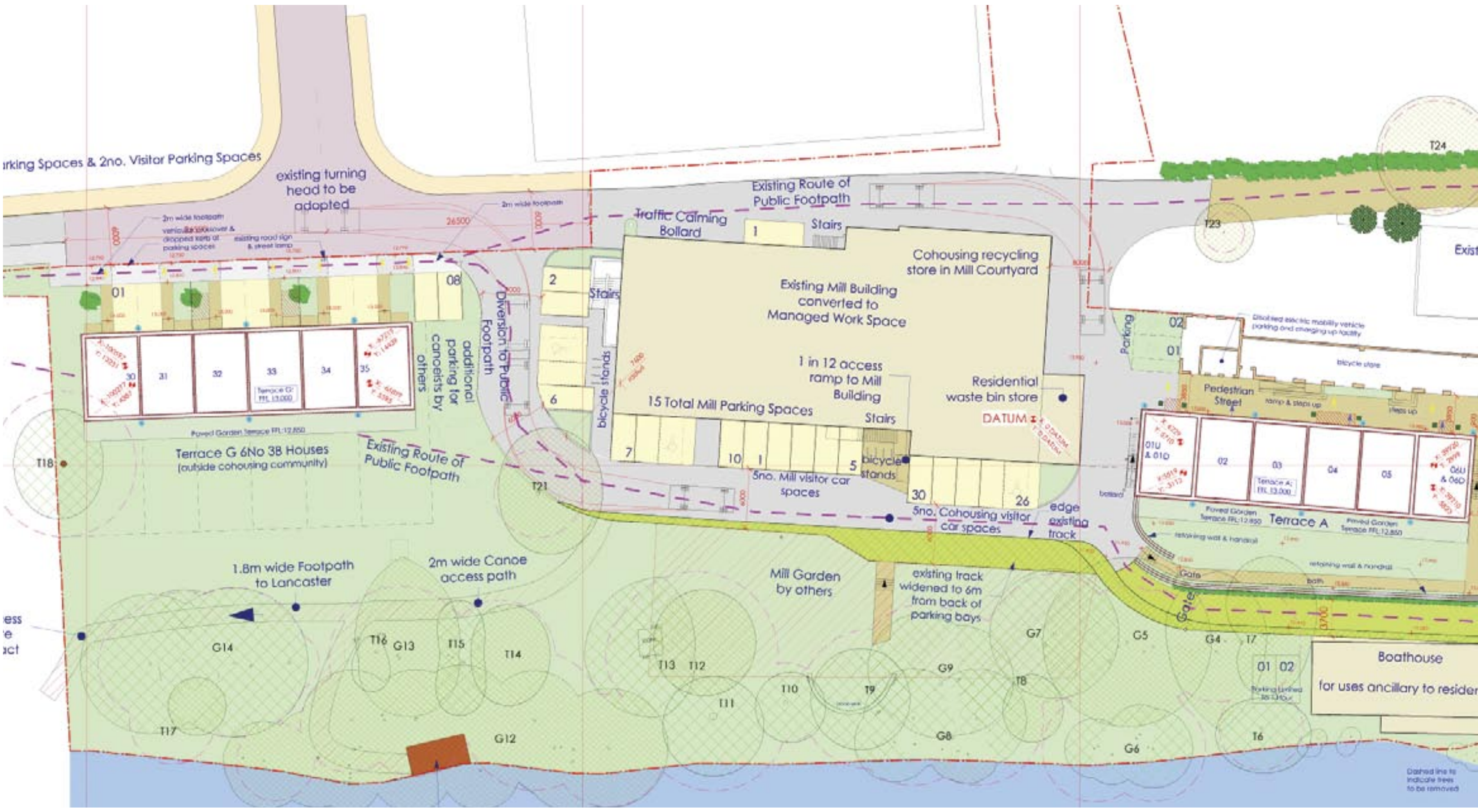
Lancaster co-housing project is a certified Passivhaus/ CSH level 6 and Life Time Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects. Eric Parks, Jon Sear and Andrew Yeats bring us the latest update on the progress of the project.

Work has now progressed well on site on the largest certified Passivhaus co-housing project in the UK, with forty one individual households, ranging from one bed flats to three bed family houses, along with shared community facilities. In this third article we cover an overview of how we have designed the project to Code for Sustainable Homes, level 6.

Lancaster Co-housing, from its conception, has aimed to be a cutting edge example of sustainable design and living. The vision, agreed amongst the initial members, also states that the project will be built on ecological values, and act as a catalyst and inspiration for significant improvements in the sustainability of new development. The decision to design and certify all homes to Passivhaus standard ensures a rigorous approach to the energy performance of the buildings. But whilst Passivhaus addresses, arguably, the biggest single impact of the development, sustainable design and living clearly goes much further than this.

The founder members had a good understanding of environmental sustainability. However, it was agreed holding these values at the centre of decision making would not be enough. A benchmark was needed, so that prospective members would be clear where priorities lay and to ensure they remained priorities. Lancaster Co-housing was always aware that the Code for Sustainable Homes (CSH), and its predecessor BREEAM Ecohomes, were not perfect. But devising a measurable standard that covers all aspects of sustainability in new housing, that no developer can wriggle around, is not easy. The idea of devising a 'code' specifically for this project was discussed. This would have left the group to decide what should take precedence when different elements of sustainability were in conflict – but the risk of getting bogged down in debates about why x, y or z was or wasn't an important sustainability issue led to this option being abandoned.

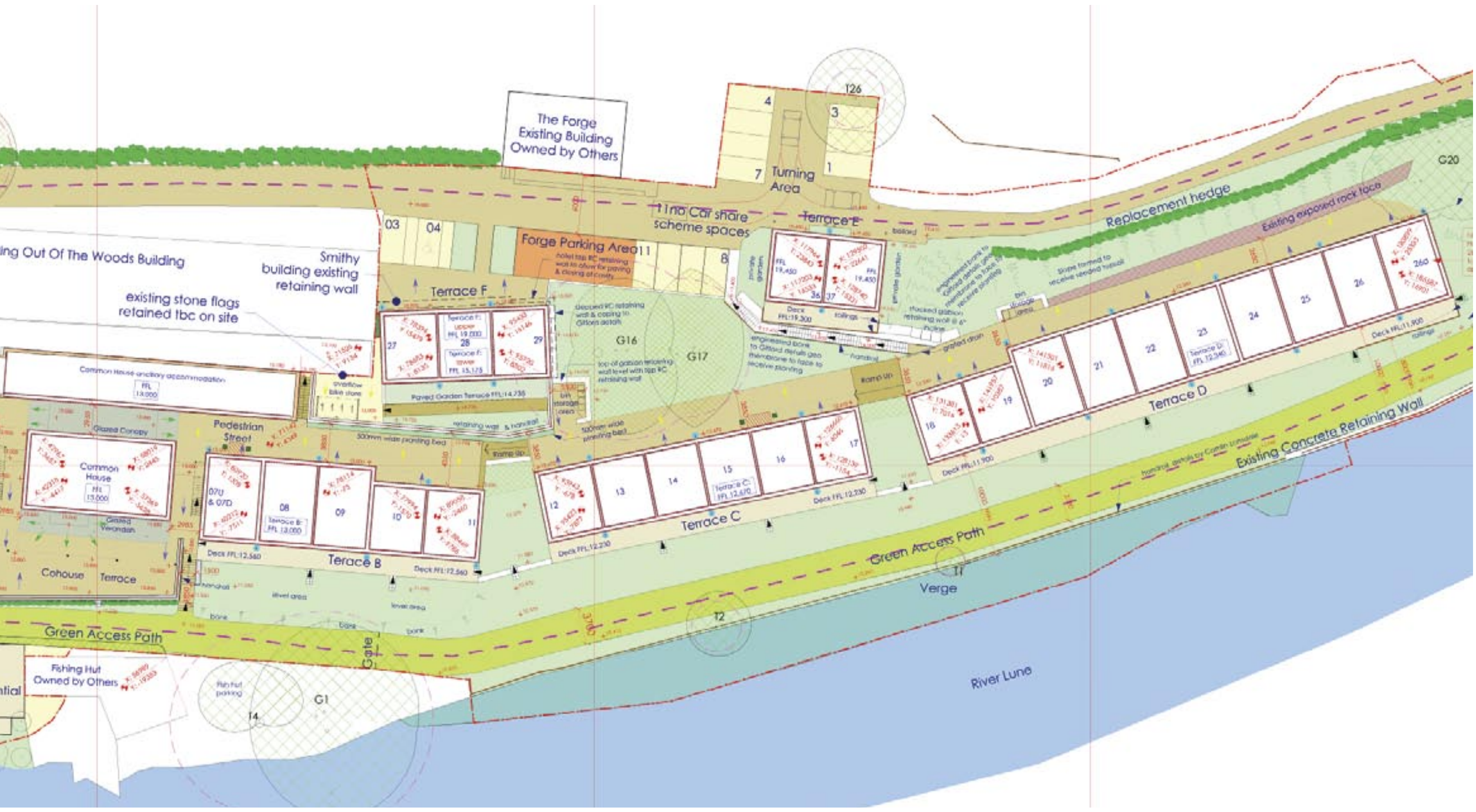
So, in line with the bold vision, the group decided to aim for the top level six of the Code for Sustainable Homes. Crucially, this decision was taken at a very early stage in the design process so it became an integral part of the design brief, rather than requiring expensive late design changes. A caveat was added allowing a deviation from the approach prescribed by the code where there was a



Above: showing the project well underway with many of the masonry structures completed ready for roofing. Below: the site layout.

'clear and credible' justification. There have been one or two frustrations with the Code, as detailed below, but in the end none were big enough to justify not getting the Level 6 accolade. There are still a few houses left to sell and 'all homes have been designed to Code for Sustainable Homes, level 6', is much clearer than a statement that could be interpreted as greenwash.

The faults in the Energy and Water categories of the Code are covered well by the Good Homes Alliance analysis in Autumn 2008 issue of Green Building magazine. Although we are also critical of certain aspects of the Code, what follows is primarily a description of the challenges that have arisen on this ambitious project and how the credits in most of the Code categories have been obtained. The general approach was to fully understand the implications of client and design team choices on the likely



Code level of the project or dwelling types from a very early stage. This was achieved through a series of participatory workshops where various design options were vetted against the Code with the client group and architects.

Many of the credits awarded have been in the design from pre-planning stages. However, there have been inevitable revisions, omissions and additions that have variously influenced the Code level that could be achieved. The most dramatic change has arguably been the decision by the co-housing group to make the most of their location on the banks of the River Lune and link a 160kW hydro-power scheme by private wire to the development. This ensures the scheme's ability to reach Code level 6 for all dwellings.

The chart (right) shows the scoring for each of the main house types at Forge Bank. As Code 6 requires 90 points or more, there are very few credits that have not been obtained.

	Credit Category	Issue ID	Maximum Credits Available	Average Credits Awarded	% of Total Credits Available that are Awarded
Mandatory Categories (Need to achieve min. requirements)	Energy / Co2	Ene1: Dwelling Emission Rate	15	15	100%
		Ene2: Building Fabric	2	2	
		Ene3: Internal Lighting	2	2	
		Ene4: Drying Space	1	1	
		Ene5: Energy labeled White Goods	2	2	
		Ene6: External Lighting	2	2	
		Ene7: Low or Zero Carbon Technologies	2	2	
		Ene8: Cycle storage	2	2	
		Ene9: Home office	1	1	
	Water	Wat1: Indoor water use	5	5	100%
		Wat2: External Water Use	1	1	
	Materials	Mat1: Environmental Impact of Materials	15	9	71%
		Mat2: Responsible Sourcing: Main Eleme	6	5	
		Mat3: Resp. Sourcing: Finishing Elements	3	3	
	Surface Water Run-off	Sur1: Mgt. of Surface Water Runoff	2	2	100%
		Sur2: Flood Risk	2	2	
	Waste	Was1: Storage of Household Waste	4	4	100%
		Was2: Construction Waste Management	2	2	
		Was3: Composting	1	1	
Optional Categories	Pollution	Pol1: Global Warming Potential of Insular	1	1	25%
		Pol2: NOx emissions	3	0	
	Health and Wellbeing	Hea1: Daylighting	3	3	100%
		Hea2: Sound insulation.	4	4	
		Hea3: Private Space	1	1	
		Hea4: Lifetime Homes (Mand. For level (	4	4	
	Management	Man1: Home user guide	3	3	100%
		Man2: Considerate contractors scheme.	2	2	
		Man3: Construction site impacts.	2	2	
		Man4: Security	2	2	
	Ecology	Eco1: Ecological value of site	1	1	78%
		Eco2: Ecological enhancement	1	1	
		Eco3: Protection of ecological features	1	1	
		Eco4: Change in ecological value of site	4	4	
		Eco5: Building footprint	2	0	

Ene 1 – Dwelling Emission Rate
Ene 2 – Building Fabric

All 15 of the available credits in the Ene1 section were obtained for every dwelling on the site. Because the predominant dwelling form on the site is a terraced property, the Ene2 for credits were also awarded as all of the houses had heat loss parameters below 0.6. It is worth noting that despite the high standards of design and energy saving performance to achieve the Passivhaus standard for the dwellings, without the input of 50kW of hydro capacity none of the houses would have reached CSH level 6. This highlights a well known bias in CSH. No matter how much space heat and primary energy demand reduction is 'built in' to a design, the highest level is not achievable without the use of 'bolt on' renewable electricity generation of some form. Prior to the incorporation of the hydro scheme, the maximisation of PVs was considered. However, it was clear that the use of PVs alone was not sufficient to ensure that Code level 6 could be obtained site wide.

Ene 3 - Internal Lighting / Ene 6 - External Lighting

At the start of the project development, the Ene 3 & 6 credits required that light fittings be dedicated energy efficient fittings. Due to changes in EU legislation that are phasing out all incandescent lighting, these sections have been relaxed.

Wat 1 – Internal Water Use

The mandatory Code 6 requirement for usage of < 80lr/per/day was met without the use of rainwater harvesting (the 200ltr butts used in the Wat 2 – external Water Use category don't count towards this figure as they contribute to the external water usage) or greywater recycling. The AECB Good and Best Practice Water standards were used to guide the specification with the client group ultimately choosing the following:

- WC = 4 litres per full flush / 2.7 litres per half flush
- Taps = 5 litres/min
- Kitchen taps = 5 litres/min
- Shower = 6 litres/min
- Washing machine = 9 litres/kg dry load (assumed to be installed by default in the Code)
- Dishwasher 1.25 litres/place setting (assumed to be installed by default in the Code)
- Bath = 140 litres to overflow

There were also more fundamental water saving design principles (compact system design, minimisation of dead legs and insulation of pipes) applied on the project that will have significant effects on the consumption figures, but are not considered in the Code water efficiency calculator.

Sur 1 – Management of Surface Water Runoff from Site

Although the site's location on the banks of the River Lune places part of the site in high risk flood zones, the flood risk assessment established that if all of the new development was built above a specific datum point (600mm above the 0.1% 'annual exceedance probability' or AEP limit), the development site would be in a low risk flood zone.

Sur 2 – Flood Risk

Restricted site (steep slope and easements on the River Lune) and shallow rock meant that infiltration, storage ponds and, or swales would be difficult to use as surface water attenuation measures. A scheme was developed by Ramboll that proposed the following measures to satisfy the mandatory and optional credits in the Sur 2 category:

- Permeable paving with cellular storage to parking near terrace G
- Oversized pipes in proposed surface water drainage system
- Cellular storage tanks in combination with the above

Mat 1 – Environmental Impact of Materials
Mat 2 - Responsible Sourcing (Basic Building Elements)
Mat 3 – Responsible Sourcing (Finishing Elements)

In looking solely at the Materials' categories, see the chart below, there are two things that stand out:

1. The variation of the credits across the dwellings types.
2. Their relatively low percentage of credits awarded relative to the maximum available.

The variation is mostly down to the fact that the materials' credits are assessed by volume or percentage of materials, and whether or not certain elements are present in any given design type. Although the majority of the Lancaster development is terraced housing, the mix of 1, 2 & 3 bed dwellings means that there are several different conditions that had to be assessed.

The relatively low percentage of points (7-10 out of a possible 15 or 47%-67%) awarded is essentially down to the fact that unless the proposed construction elements are found in the Green Guide for Materials, an assessor has to make an educated guess as to what credits will be awarded. When it comes to non-standard construction build-ups, the Green Guide is very limited and most of the construction build-ups on this project require bespoke assessments to be completed by Stroma (the licensing body for the Code assessor in this case) and, or BRE (the author of the code and originator of the Green Guide).

Was 1 – Household Waste Storage and Recycling Facilities

The requirements for the Was 1 credits are generally straightforward, specifying adequate storage and access for waste and recycling, and are driven by the type of waste and recycling service (pre- or post- collection sorting) offered by the project's local authority. Where the Lancaster scheme departs from the typical requirements for the Was 1 is in the introduction of an alternative scheme for the distribution of external bins and bin storage. We sought to avoid the 'bin alley' effect of placing individual wheelie bins outside the north entrance of each dwelling along the pedestrian street. An alternative arrangement was designed to provide a communal bin store at the west end of the pedestrian street (adjacent to the Mill) and have fewer bins along the pedestrian street grouped in alcoves and rotated on a regular basis by the residents.

Pol 1 – Global Warming Potential of Insulants

In the Pol 1 category, credits are awarded for selecting insulation materials with low 'global warming potential' (GWP). In most cases this was done by specifying fibrous, non-foamed insulation materials that use no greenhouse gas based blowing agents in their manufacture. Where foamed insulations have been used, they use a blowing agent that satisfies the low GWP standard.

Pol 2 – NOx Emissions

The Pol 2 NOx emissions category awards credits to space heat and hot water systems that have low NOx emissions. The choice of a centralised community woodchip boiler (with higher NOx emissions than gas or oil, for example) means that the Pol 2 credits were not obtained here.

Hea 1 – Daylighting

The daylighting requirements in Hea 1 were easily met and exceeded with the generous south facing glazing, important in increasing solar gain and also providing very

			Dwelling Type									
		Maximum Credits	1 Bed Ground Floor	1 Bed First Floor	2 Bed, Mid terrace	2 Bed, Mid terrace	3 Bed, Type 1, Mid terrace	3 Bed, Type 1, End terrace	3 Bed, Type 2, Mid terrace	3 Bed, Type 2, End terrace	3 Bed, 3 Storey Mid terrace	3 Bed, 3 Storey End terrace
Materials	Mat1: Environmental Impact of Materials	15	7	10	9	10	9	9	9	9	10	10
	Mat2: Responsible Sourcing: Main Elements	6	4	4	6	6	4	6	6	6	6	6
	Mat3: Resp. Sourcing: Finishing Elements	3	3	3	3	3	3	3	3	3	3	3

good daylight levels. Additionally, the open floor plan design helps ensure that 80% of the working plane has good daylighting.

Hea 2 – Sound Insulation

As far as was possible, Robust Details have been used on all separating walls and floors to ensure credits for Hea 2 are obtained. Elements ineligible for Robust Details will be tested once construction is complete.

Hea 3 – Private Space

The provision of adequately sized (1.5m^2/bedroom) private external space to each dwelling was not an issue in the early stages of the design. However, when external ground level to the south-facing terraces was lowered, disabled access to the private spaces was no longer available. Those dwellings with first floor balconies still technically met the standard, as they were in theory accessible – via stair lift and level access to the balconies. For those dwellings without balconies, an alternative was devised to provide replacement private space along the Pedestrian Street. As required by the Code, the space will be clearly defined as belonging to a specific dwelling and its occupants through the use of fencing or planting.

Hea 4 - Lifetime Homes

The 2010 version of the Lifetime Homes (LTH) checklist was adopted in favour of the default 2009 version. The 2010 version offers the simpler (and cheaper) option of ensuring the space for a future lift installation is provided on the ground and first floor plans without requiring the trimmed opening to be built-in during construction.

Man 1 – Home User Guide
Man 2 – Considerate Constructors Scheme
Man 3 – Site Constructions Impacts
Man 4 – Secured By Design

Three of the four above categories are relatively straight-forward to obtain credits for, but Secured by Design introduced a potential conflict with the Passivhaus design. One of the requirements of Secured by Design is for laminated glass in all ground floor windows and glazed doors. The use of such glass results in a decrease in the g-value of the glazing and an increase in the U-value of the window. The use of laminated glass in the ground floor doors and windows has been limited on this scheme based on advice from the ALO.

Eco 1 – Ecological Value of Site
Eco 2 – Ecological Enhancement
Eco 3 – Protection of Ecological Features
Eco 4 – Change of Ecological Value of Site
Eco 5 – Building Footprint

The Eco1-4 credits, essentially covering the existing ecological value of the site and the level of proposed improvements, were assured through the following measures:

- Ecological survey to assess and confirm the ecological value of the site.
- Adoption of recommendations to protect existing features and improve the ecological value of the site.
- Design of soft landscaping scheme that created a significant improvement in the number of species.

The degraded grassland, woodland and riverside habitats within the site have significant potential for enhancement, so once the CSH methodology was well understood, the required increase in ecological value was easily achievable.

The Eco 5 'Building Footprint' credit is awarded to dwellings, or groups of flats, that have a high ratio of net internal floor area: net internal ground floor area. This obviously favours developments of multi-storey dwellings. Development at Forge Bank was limited to two-storeys after initial consultation within the village.

Eric Parks, Jon Sear and Andrew Yeats

Eric Parks is an architect and certified Passivhaus designer who has specialised solely in the field of ecological design and sustainable construction. He currently runs his own architectural practice and consultancy. He is a long serving member of the AECB. Recent work includes (through the AECB), working with the Technology Strategy Board (TSB) and Pheriche web designers to develop a national database of exemplar, low-energy refurbishment and new-build projects. Eric also regularly acts as a trainer on the AECB CarbonLite Passivhaus Designer courses.

Jon Sear is a freelance project manager, environmental consultant, and a future resident at Forge Bank. Jon was a co-founder of the Lancaster Co-housing project and has worked for the last two years as the client representative/ project manager in the participatory design team.

Andrew Yeats (editor) of Eco Arc Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for co-housing having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years.

Lancaster co-housing project.

(part four)

The Lancaster co-housing project is a certified Passivhaus/Code for Sustainable Homes, level 6 and Life Time Homes, affordable community housing project. It has evolved through a participatory design process with the individual householders and Eco Arc Architects. In this article Andrew Yeats and Graham Bath provide an overview on the wall construction, and first floor construction, with particular regard to the integration of Passivhaus detailing.

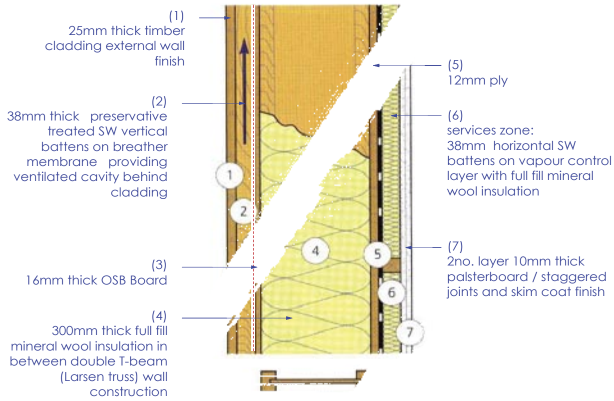
Work on the largest certified Passivhaus co-housing project in the UK has progressed well since the aricle in the previous issue of Green Building magazine. The project, when complete, will consist of forty one individual households, ranging from one bed flats to three bed family houses, along with shared community facilities.

The Lancaster co-housing project, from its conception, has aimed to be a cutting edge example of sustainable design and living. The decision to design and certify all homes to Passivhaus standard ensures a rigorous approach to the energy performance of the buildings, with attention to detail to ensure continuity of the insulation throughout the external fabric with minimum cold bridges at junctions of elements or penetrations through the fabric for doors and windows etc.

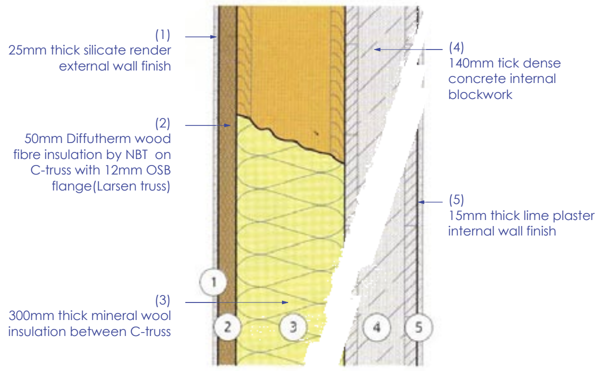
Super insulated wall construction types that were considered at the outset of the project

Eco Arc has been building 300mm wide super insulated cavity walls (originally with Peter Warm and David Tasker with imported Danish wall ties) since 1992, initially at York Eco Centre & Heeley City Farm. From the same time period we have been building 300mm wide super insulated Masonite I beam timber frame constructions, with the first one being David's House in Wales. Our projects have been featured in previous issues of this magazine. However, we had not built to the exacting Passivhaus standard before. We decided to go back to basics and prepared eight wall type construction options (each described/illustrated below) for project team review.

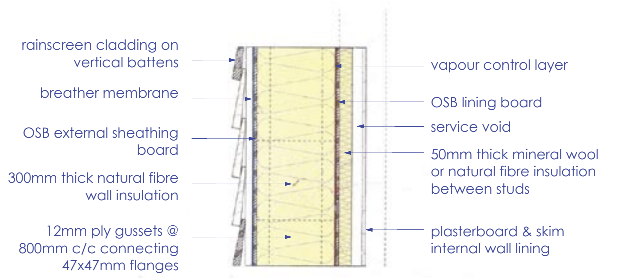
1. 500mm wide masonry cavity wall with 300mm insulation in cavity with render or timber boarded external finish.
2. 200mm solid stud timber frame (type A) over clad with Driffutherm & render external finish
3. 300mm timber I-beam stud timber frame (type B) with timber boarded finish.



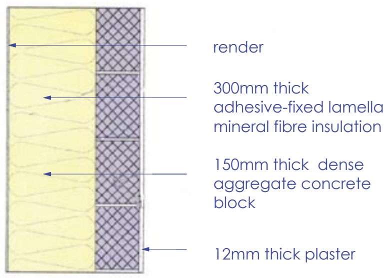
4. 300mm plywood web timber frame outer leaf & 140mm blockwork inner skin / render finish.



5. 300mm plywood gusset timber frame outer leaf and 140mm blockwork inner skin / boarded finish.
6. 300 mm plywood gusset timber frame wall detail/ boarded finish.



7. 300mm adhesive applied external insulation & render finish with 140mm masonry blockwork inner skin.



8. 425mm solid clay block wall with Perlite integral insulation and 40mm external insulated render.

The wall types finally selected

After much deliberation and discussion (with some strongly held views by various parties) within the project team of the pros and cons of the eight wall options on the table, along with a thorough cost review and program review of the consequences of each option, we settled on the traditional cavity wall. Interestingly, with one of the timber frame options we would have saved 10 weeks in the overall construction program, but even allowing for the reduced contract preliminaries it would have cost £80,000 extra to the total projected contract sum.

The contractor was particularly keen on the cavity wall option as the north of England seems to be dominated by traditional masonry trades. Graham Bath had watched Bill Butcher's Denby Dale video several times and gained the confidence he needed to train his team to deliver the same Passivhaus exacting standard in Lancaster.

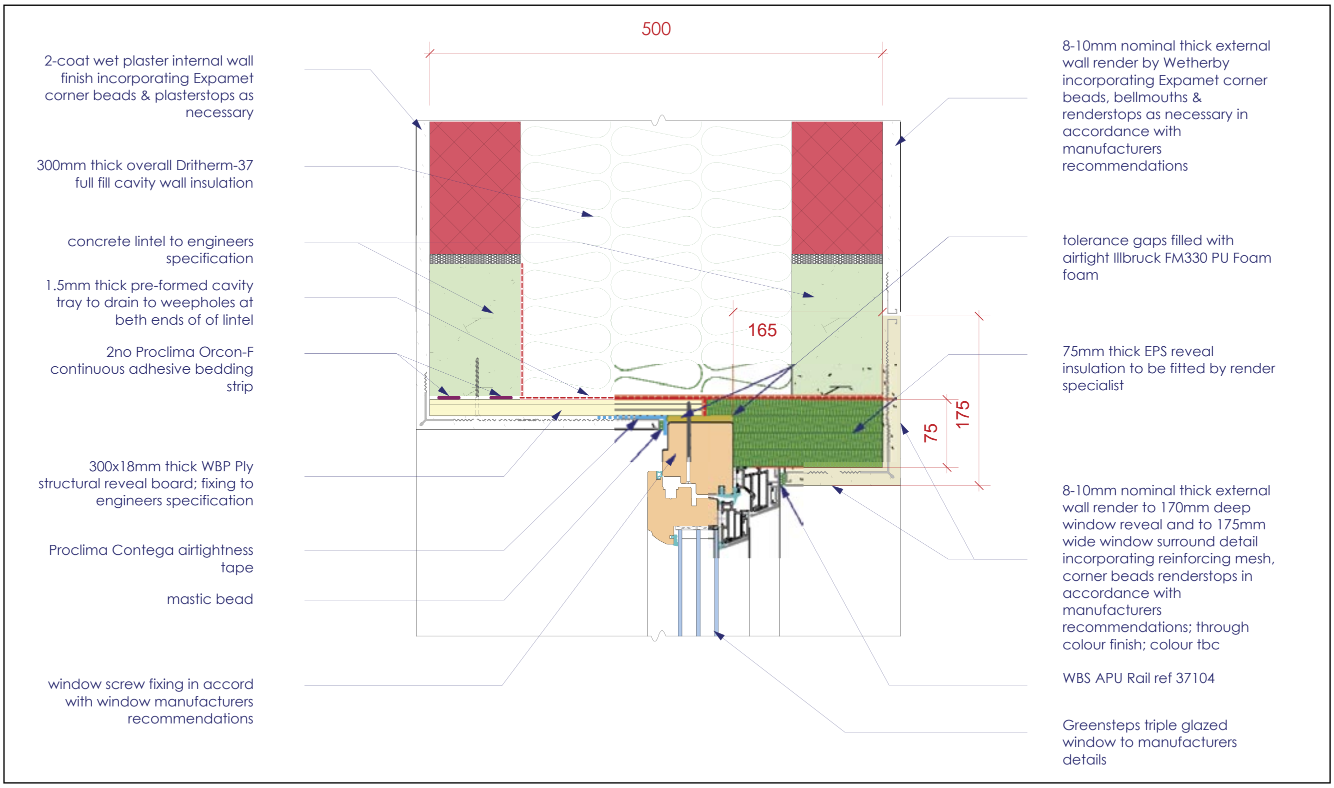
The cavity wall option would not frighten off the locally available tradesmen, it would allow us to build in some thermal mass and it was the cheapest option on the table, allowing us to deliver more affordable homes to the client group. We also understood the key disadvantages; relating to construction quality control for good performance being hard to check and manage on site, and the need to work hard to design out traditional thermal bridges, with having some structure inside and some outside.

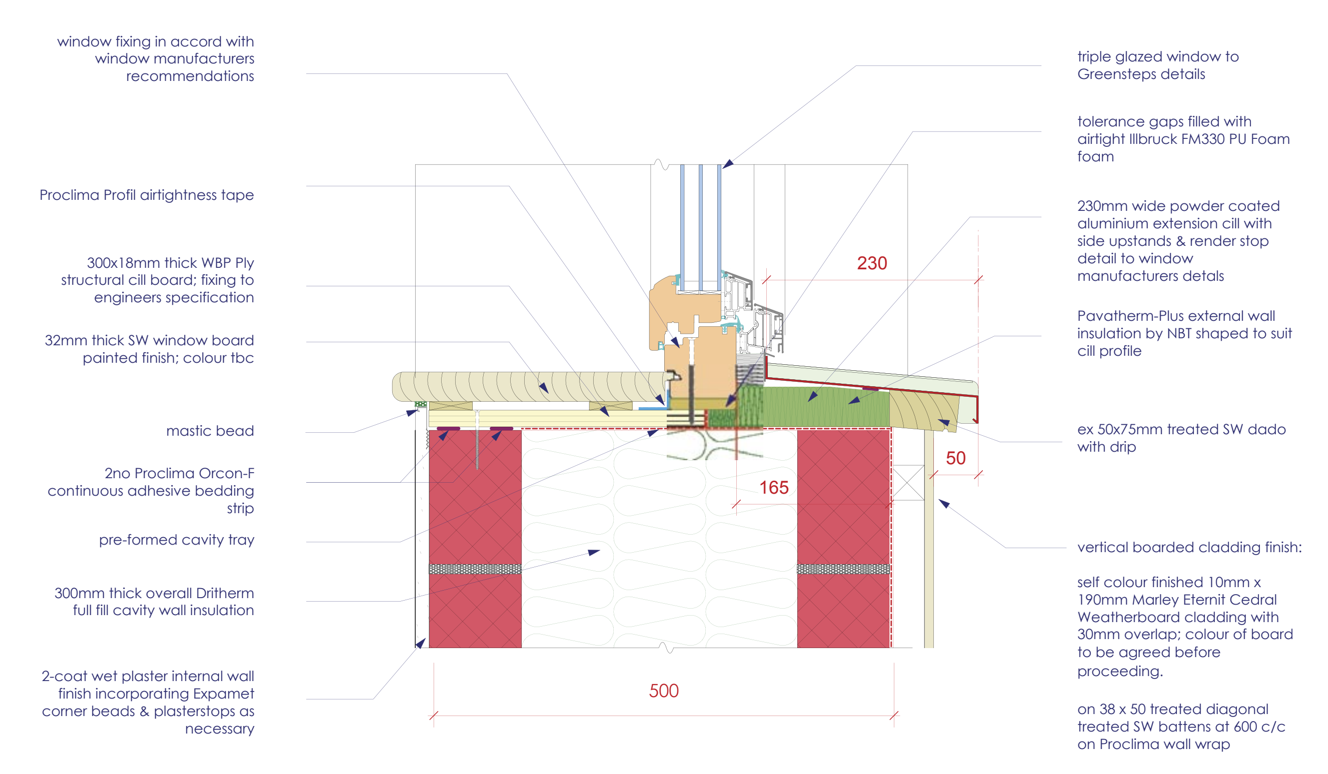
Although the cavity wall was generally agreed upon (Figs 1 and 2), it was clear the wall facing the river to the south elevation was going to be mostly door or window and the small gaps between would be best as timber frame, so a 9th option was developed with Ramboll, the project engineers, for a 38mm wide, 300mm deep, Kerto structural timber frame panel system, insulated between the studs and externally insulated with Pavatherm Plus wood fibre insulation and clad with Operal fibre cement/ cellulose board (see Fig 3).

The key details to note, that enhance this conventional cost effective cavity wall detail up to Passivhaus standard, are described below.

300mm wide cavity, full filled with Dritherm 37 (or in some houses Dritherm 32) recycled glass, soft mineral insulation. To give an effective wall U-value of $0.12W/m^2K$ and $0.10W/m^2K$ respectively. Initially we started with three rolls of 100mm wide insulation, with staggered joints but

Fig 1. 300mm insulated masonry wall construction/externally insulated window head detail.





Fig/ 2. 300mm insulated masonry wall construction/externally insulated window cill detail.

had expansion problems with the roll distorting the green block work over night in the damp air. We changed to two layers of 150mm which alleviated the problem.

Basalt Teplo wall ties, which surprisingly don't transfer heat across the cavity and don't figure as a cold bridge in PHPP.

Independent and separated internal and external lintels over openings. We looked at GRP combined lintels and cavity closers, but this simple separated detail worked out much less expensive.

Partial 18mm WBP ply box to close the cavity to the back of the window head. Interestingly both the engineer and contractor wanted to take the ply box right across the cavity to tie both leaves together but Alan Clarke and Nick Grant calculated in PHPP/Therm it would amount to 1.0kWh/m^{2}yr heat loss a year through the linear cold bridge and would cause us to fail the Passivhaus target for certification. Air tight tapes seal the back face of the window head to the ply box, which is then concealed with the skimmed plaster board soffit.

Externally over insulating the window head and window reveal with 75mm EPS insulation up to the front face of the window unit, combined with the partial ply box, reduced the cold bridge Psi value down to a good value of 0.01, which was acceptable in PHPP.

Setting the window unit back 165mm from the face of the wall was the optimum location in terms of reduced shading for the soffit over hang, whilst still being towards the middle of the insulation zone, and being partially isolated form the cold outer leaf wall elements.

The use of high performance Passivhaus certified externally insulated/aluminium clad window frames provided by Greensteps, using the German Gutmann window alu frame components with 48mm and 52mm triple glazed low E, argon filled glazing with a glass U-value of 0.60W/m^{2}K, with an Insulated Thermix Spacer PSi value of 0.036, giving a window frame U value of 0.80W/m^{2}K, and a total unit installation U-value of 0.9W/m^{2}K. Initially we had problems with the Secure By Design requirements, which required laminated glass to all ground floor windows which both reduced U-value performance and the g-value of the glass, but the police ALO relaxed his requirements in some areas due to the high level of neighbourhood watch provision inevitable within a co-housing scheme.

The windows have been tested to 1350 Pa (equivalent to force 14 and 102mph wind speed) for water-tightness and they weren't leaking when the test was stopped, which indicates the units will be extremely air tight under normal conditions.

A clever Wetherby Render APU rail allowed for a wind and water tight, flexible seal at the junction of the external through colour render and the external face of the aluminium frame to the window units.

As above the partial 18mm WBP ply box was used to close the cavity to the back of the window cill. This was combined with insulating below the window cill with Pavatherm Plus insulation up to the front face of the window unit. This reduced the Psi value down to a good value of 0.016, which was acceptable in PHPP. Air tight tapes seal the back face of the window cill to the ply box, which is then concealed with the window board set in to a rebate at the back of the window.

Down to DPC level around all the house perimeters, below a consistent window cill dado line, the external wall render was substituted with Eternit Cedral weatherboard cladding on battens. To ensure the cavity insulation remained in a wind tight void to avoid thermal bypass, the external air porous blockwork was protected with a wind tight barrier of Proclima Solitex Wall Wrap.

The infill timber frame walls to the south elevation was developed as a 38mm wide x 300mm deep Kerto structural timber frame panel system, with OSB sheathing, fully insulated between the studs and externally insulated with 100mm Pavatherm Plus wood fibre insulation and clad with battens & Operal/Cedral fibre cement/cellulose cladding board.

Over insulating the window head and window reveal with 100mm wood fibre insulation up to the front face of the window unit reduced the cold bridge Psi value down to a good value, which was acceptable in PHPP. Air tight tapes seal the back face of the window unit to the Proclima Intello vapour control layer over the Kerto structural frame with the taped joint concealed with the skimmed plaster board reveal board.

Setting the window unit back 160mm from the face of the wall was the optimum location in terms of reduced shading for the soffit over hang, whilst still being towards the middle of the insulation zone, and being partially isolated form the colder external elements. To avoid any services penetrating though the internal air tight barrier, or the insulation zone, a 25mm battened out service void was created behind the plaster board inner skin. >>

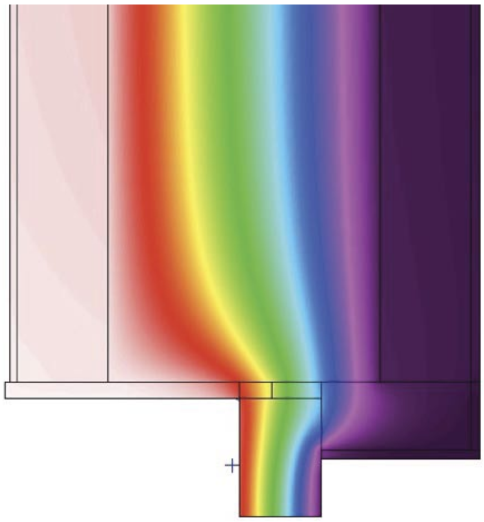
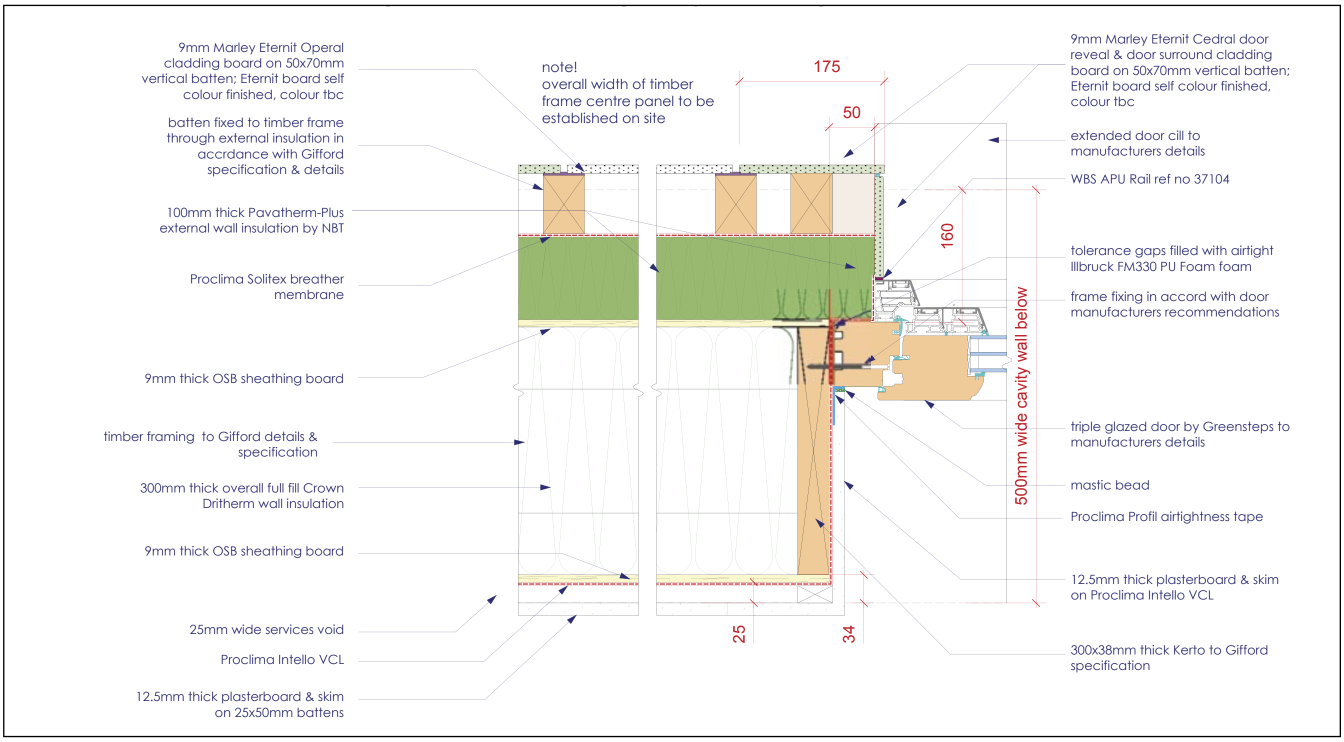


Fig. 4. Therm diagram to illustrate the attention to detail required by PHPP to ensure the integration of the window units where cold bridge free at all junctions.
Courtesy of Alan Clarke & Nick Grant.

Fig. 3. 300mm Kerto timber frame panel wall construction. (to south wall only between doors & windows).



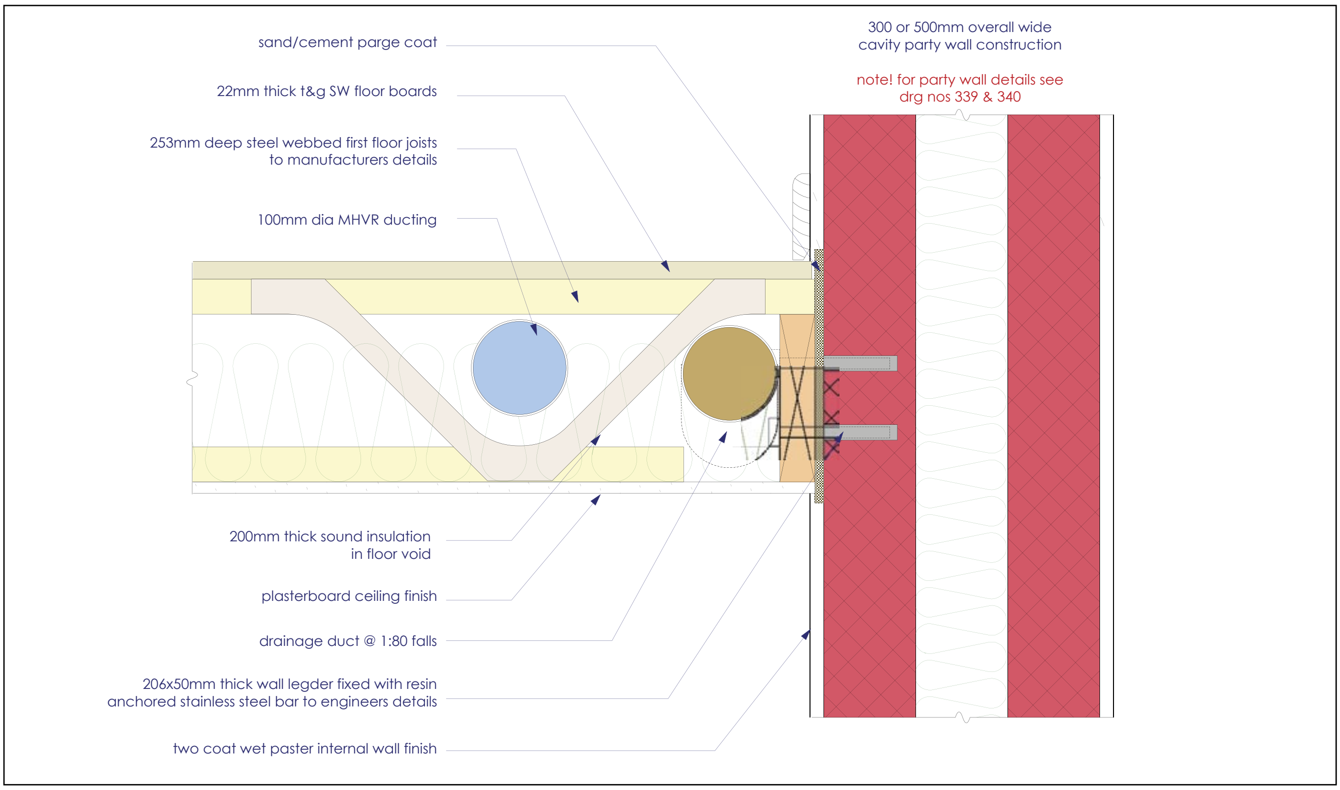


Fig 5. Intermediate floor construction within a single dwelling.

One of the requirements of Passivhaus design is 'thermal bridge free' details. The heat loss through poorly designed junctions can exceed that through the actual floor, roof and walls when they are insulated to Passivhaus levels.

Fig. 4 shows the thermal performance predictions at the wall junction (head and reveal) developed for this project. The problem we have is the transfer of heat from the warm inside through the weak link in the connection details around the window to wall abutments. The solution was to bring the window head inboard in to the depth of the cavity insulation zone and over insulate the window unit with 75mm EPS insulation. Although not often seen in the UK this is a standard Passivhaus detail on the continent. The Therm analysis provides an accurate prediction of the heat loss through the junction using detailed numerical analysis to 'solve' the steady state of heat loss and temperature throughout the construction, hence the 'isotherms' of equal temperature on the diagram. Using the results of the analysis we calculated the thermal bridge factor in terms of watts/m/K, and added in the estimate of the total heat loss in PHPP.

As most energy conscious designers/builders will know by now, supporting the first floor joists by bedding them in to the inner leaf of a cavity wall is a cardinal sin and a guaranteed way of creating multiple air leaks around the perimeter of the building. At Eco Arc we have been using perimeter ledger plates bolted to the wall for 20 years as an alternative, but not realising air can still escape behind the ledger plate through the porous holes in the block work in to the cavity. At Denby Dale, Bill Butcher finally nailed the detail in an air tight robust Passivhaus manner by parging behind the ledger plate first to seal the porous surface of the block wall, and ensuring the fixing bolts are stopped before fully penetrating the inner leaf of block work in to the cavity. On this project we adopted this tried and tested detail.

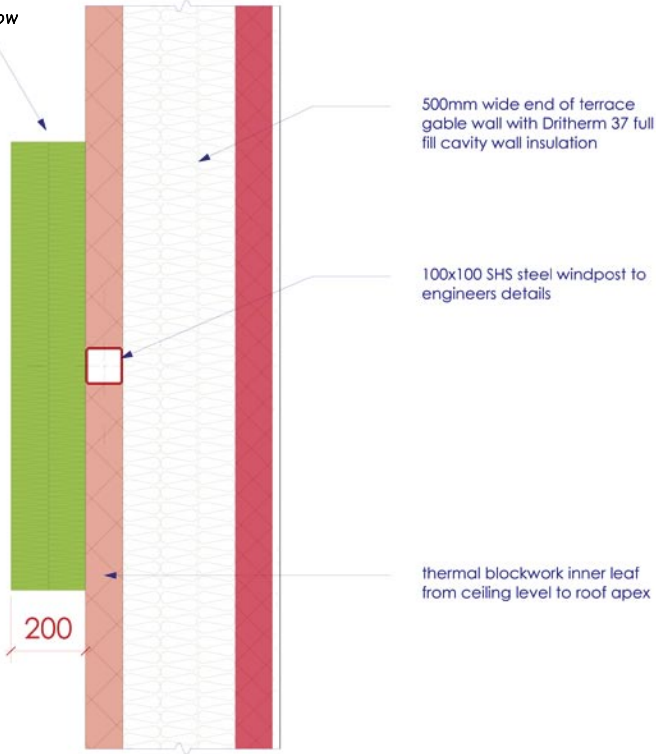
As with any Passivhaus we needed to accommodate extensive MVHR duct work. Using open web posi joists to form the intermediate floor gave us more scope for routing ducts, cables and soil pipes through the floor without having to have bulk head boxings to the ceiling below, or core drilling the webs of every I beam floor joist.

Interestingly as shown in Fig 5 the structural formation of the steel webbed joist allowed us to cut away the bottom flange in critical locations to allow us to gain the required fall in a waste pipe without impairing the structural integrity of the joist.

Problems discovered and overcome on site

Originally the project design included for open cathedral ceilings within the insulation zone on the slope of the pitched roof from eaves up to the ridge level. As part of the inevitable post tender value engineering phase we reluctantly agreed to drop the vaulted ceiling to flat ceilings to realise a cost saving of £177,000 across the project to get back on budget. In the original design the

Fig 6. Shows gable window posts over-insulated to reduce cold bridge to a permissible level in PHPP.



The builders' experience so far

Following our selection as preferred contractor for the Lancaster co-housing project we were embraced by the client and their consultants into the project team at an early stage. Whilst the fundamental design principles had been established, we were able to contribute to the practicality of the detail design throughout a regular series of team meetings during the 12 months prior to commencement on site.

These project meetings enabled us to understand the philosophy of the client and their design team to achieve Code for Sustainable Homes, level 6 and Passivhaus accreditation. Whilst we had carried out various schemes for housing associations throughout the Northwest to CSH level 4, the project brought new and exciting challenges, particularly due to the utilisation of masonry construction, rather than the more usual timber frame or prefabrication solutions.

One of the primary requirements of the Passivhaus Standard is to achieve an airtightness level of 0.6m³/hr/m² @ 50Pa and with the current Building Regulations at 10m³/hr/m² @ 50Pa this was seen as the major challenge on the project. We had, for some time previously, been achieving levels below 5.0 and as low as 2.2 but the Passivhaus requirement set new standards.

In conjunction with the design team we selected an air testing company and appointed an 'airtightness champion', both with Passivhaus experience, to advise and assist in achieving this rigorous standard.

The Airtightness Champion is employed full time on site to install all air barrier membranes, taping and to carry out air leakage tests at critical stages of the construction. He also oversees the activities of all other trades during this process to ensure and maintain the integrity of the air tightness and thermal barriers.

We are presently approaching plaster stage on the first properties so we await our first full preliminary air test, which will be carried out as soon as one house is plastered, but air leakage checks previously carried out indicate that we are on the right track. The traditional two coat wet plastering provides the primary air tightness barrier with pre-installed proprietary tapes and seals at all junctions, changes of direction and entries. Extensive parging is also being carried out to the blockwork behind services, timber supports, bearers etc which overlaps with the plaster basecoat.

One other defining aspect of the progress on site has been the process required to resolve day to day queries which often require the consideration of various members of the design team to ensure that Passivhaus standards are maintained, particularly with regard to thermal breaks, airtightness etc... Whilst this has affected progress on the early plots we are confident that the steep learning curve experienced will prove beneficial during the construction of the remaining properties.

Graham Bath of Whittle Construction Ltd

External EPS insulation to window before being rendered over (as in Figs a and 2, seen from outside).

Rendered over-insulated window to north wall (as in Figs 1 and 2, seen from outside).

Internal airtight taping and vapour control layer of south, timber wall (as in Fig 3, seen from inside).

Internal airtight tapping to plywood boxing of window reveal in masonry north wall (picture of Fig s 1 and 2, from Inside).

Fig 7. Various shots of airtight tapes and exterior view of over-insulated window.

project engineers at Ramboll had sensibly allowed for a single 100x100 RHS gable wind post within the inner leaf of block work from ground floor slab level to ridge line at the end of each terrace.

It was only with the erection of the first terrace on site, with the new design of flat ceiling, did we realise (in horror) that the old wind post was still in the engineer's design, penetrating through the flat ceiling insulation zone, creating a terrible cold bridge. After sweating palms for a while and Alan, Nick and Peter Warm running several Therm analysis trials through various parts of the cold bridge, did a mitigation solution emerge. With the problem exposed the structural engineer was able to design out the wind post above the insulation zone on future terraces, and Whittle Construction duly cut down the remaining un-installed wind posts left on site to make sure it did not happen again.

Airtight tapes not sticking in wet conditions

Once we were wind and water tight with the first new house in terrace A, Paul Jennings & Mike Neat set up an airtightness induction training day for the project team and key Whittle Construction operatives on site. It had became clear early on in preparation for the day that many of the ply window boxes had been taped when wet and the junction of the block walls to the ground floor slab had also been taped in damp conditions. Consequently the stickiness of some of the tapes were starting to fail. Some even had to be removed and Mike Neat invested in a room heater and a hair dryer to locally dry out the substrate before re-taping and resuming the door air blower tests on a house by house basis.

In the next article (fifth) we will further review the air tightness strategy and works in progress.

Andrew Yeats and Graham Bath

Credits

Client: Lancaster Co-housing, represented by Jon Sear as Client Project Manager

Project architects: Andrew Yeats, Vincent Fierkens & Lucy Nelson of Eco Arc Ecological Architecture Practice

Main contractor: Graham Bath & Charles Whittle of Whittle Construction.

Project manager and quantity surveyor: David Fotheringham of Turner and Holman

Structural civil engineer: David Tasker & Gary Willis of Ramboll

M&E engineer & certified Passivhaus designers: Alan Clarke &Nick Grant

District heating system designer: Steve Pettit &Rob Clegg of Pettit Singleton Associates

Passivhaus certifier: Peter Warm

CSH & Life Time Homes consultant: Eric Parks

Andrew Yeats of Eco Arc Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for co-housing having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years. Andrew has recently qualified as a certified Passivhaus designer.

Graham Bath is managing director of D Whittle Construction Ltd, the main contractors for the Lancaster co-housing project. He has over 40 years experience of social and private housing in the Northwest and has been actively involved in ecohomes and Code for Sustainable Homes over the past 10 years.

Lancaster Cohousing project

(part five)

Lancaster Cohousing Project is a certified Passivhaus / Code for Sustainable Homes, level 6 and Life Time Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects.

Since the article in the last issue, work on the largest certified Passivhaus co-housing project in the UK is still progressing well on site. The project consists of forty one individual households, ranging from one bed flats to three bed family houses, along with shared community facilities. In this part five article, we cover an overview of the airtightness strategy to deliver Passivhaus exacting standards of less than 0.6 ACH^{-1}@50Pa.

Lancaster Cohousing, from its conception, has aimed to be a cutting edge example of sustainable design and living. The decision to design and certify all homes to Passivhaus standard ensures a rigorous approach to the energy performance of the buildings, with attention to detail to ensure continuity of the air tightness barrier throughout the external fabric, with minimum penetrations through the fabric at junctions of elements and around doors and windows etc.

When the builder, Whittle Construction, adopted the principles for delivering airtightness outlined in Paul Jenning's '12 Steps to Airtightness' strategy document (see box right), they appreciated that an effective Airtightness Champion was a key component. With Mike Neate being proposed by the window supplier, Green Steps, as their specialist installer, and recommended by Paul as the airtightness champion, it was a convenient simplification for Mike and his team to take on the primary airtightness role. Mike, as the airtightness champion, included within his role confirming that units were ready for testing using an old uncalibrated fan for leakage checking. Mike's remit is to install the Pro-Clima Contega tapes around the openings, also grommets and tapes on ductwork and cable penetrations. In upper flats, and some houses, there are also sections of Intello membrane over OSB, forming the airtight barrier at the rear of service voids. This alleviates the issue identified on other projects, where even 18mm OSB has been found to permit small quantities

12 steps to achieving airtightness

1. Set airtightness target eg. PH, < 0.6ACH^{-1} @ 50 Pa.
2. Get clear on air barrier strategy – how to deliver target, eg. wet plaster on masonry walls.
3. Prepare air barrier drawings – plans & sections, what forms the air barrier, where?
4. Develop airtightness specifications – targets, materials but especially the airtightness process.
5. Airtightness design review – look for gaps, any lack of clarity.
6. Design workshop – resolve the issues identified in the review, prepare action plan.
7. Train airtightness champion – preparing the key person or persons to ensure the air barrier strategy is not compromised, require robust support thereafter from site management.
8. Airtightness delivery – the building process.
9. Site leakage audits – checking for effective sealing, looking for incomplete elements.
10. Preliminary airtightness testing – may be whole building or sometimes partial, can even test key elements off site. Normally allow 1 preliminary test for a masonry PH, 2 for timber.
11. Acceptance airtightness testing – with the building effectively complete from an airtightness perspective.
12. Post-completion review – the opportunity to learn for future projects, what worked, what didn't work?

Terrace A in progress with balconies overlooking the River Lune. These are currently being erected, along with gabion retained walls. By the time you read this article the first families will have moved in.

of leakage. Of course, this is not helped by the UK construction industry's propensity to allow stored timber products to get wet whilst on site, making it much harder to then achieve an effective air-seal. A Scandinavian-born architect friend has estimated that 75% upwards of UK timber on site would be condemned as unusable in their more rigorous quality regime! Wet timber then gives rise to failures of the premium sealing tapes, with high humidity levels preventing them achieving a robust seal. An earlier experience of this was on the Horsham Passivhaus project, where SIP panels for the last two houses to be built unfortunately got soaked on site before assembly. More than two weeks later, Tescon tape fixing Intello+ membrane onto the OSB inner face came off when we applied preliminary test pressure, because of the residual moisture.

The Lancaster Cohousing scheme is primarily of masonry construction, like the earlier Denby Dale exemplar. As a more mainstream scheme, the primary air-seal is wet plaster applied to the inner surface of the blockwork external and party walls. Particular care was taken to ensure that areas where sockets boxes, pipes and other services are to be installed, frequently requiring chasing of the blockwork, were parged beforehand to ensure an effective seal. Unfortunately it was not appreciated that this needed to extend to any blockwork

Air barrier strategy for the project

Roof

Pro-Clima Intello+ membrane on OSB sheathing to underside of upper horizontal ceilings. Plasterboard over forming service void. Similar to sloping ceilings in 3 upper flats.

Walls

Largely 15mm plaster & skim finish to form airtight barrier to blockwork external and party walls. Plaster returned into all window and door reveals. Continuous 3-5mm parge coat behind stairs and perimeter ledger plates (supporting upper floor joists). Also in all locations where blockwork is chased out for cables, pipes, socket boxes etc. Sections of timber framing on front facade, effective seal as roof.

Ground floor

150mm Slab over Visqueen over insulation, with DPM below. Contega tape with primer & Orcon-F mastic used to seal joint behind skirting board, prior to plastering. Tescon tape then used to repair damaged seals after plastering.

Interfaces

Around windows and doors, generally sealed into plaster using Contega Tape & Orcon-F mastic.
In front facades, Tescon & Profil tape seal to membranes in timber framing.
Rooflight frames also sealed to airtight membrane with Tescon and Profil tapes.

Penetrations

Sealed with appropriate Pro-Clima EPDM grommets and tapes, generally then covered over with plaster.

Right: the blower fan mounted in one of the window apertures.

Top: neat tidy taping of window units to plywood window surround boxes.
Centre: air tight parge coating behind all MVHR ducts against walls.
Bottom: trial air tight taping experiments of damp plaster wall to damp concrete slab with primer base. Nothing much would stick without drying every thing out first. Cement parging was also carried out around all electrical cable runs and back boxes.

surface, because with its PFA (pulverised fuel ash) content the blockwork was found to be very porous. Hence large holes through internal partition blockwork walls, for waste pipes and similar, needed to be fully parged to prevent lateral air movement through the blockwork. Moreover, subsequent experience has shown how easy it is for the parge coat behind socket boxes to be compromised during electrical installation.

One of the key elements of the '12 steps' approach is to define the strategy by which the airtightness target is to be achieved – no one should be under the illusion that a good level of airtightness is achieved without great care and attention to detail. Defining the strategy helps to ensure that there are no gaps in the air barrier, and that there is clarity about which products and processes are involved in delivering good airtightness. The Lancaster Cohousing air barrier strategy is summarised on the previous page. It is ideally used in site inductions and other training events to engage everyone on site with the airtightness process, particularly subcontractors, such as plumbers, who can very rapidly compromise the air barrier with their penetrations.

With the leakage check fan, Mike's team confirms that each unit is ready for the preliminary airtightness test, and then make arrangements for Paul or an Aldas colleague to attend site, ensuring that weather conditions are satisfactory – not too windy – and that there are no access or other limitations preventing testing. Once a satisfactory preliminary test has been achieved, as the airtightness champion, Mike works closely with the site manager to continuously follow-up the ductwork, electrical and plumbing sub-contractors to effectively seal around their numerous penetrations through the airtight envelope. Unfortunately, despite the best of intentions, the realities of programming on site have meant that some preliminary leakage tests have failed because of incomplete penetrations, particularly open plumbing wastes and leakage through heat recovery ductwork. Whilst these can and have been identified and then eliminated during the preliminary testing, it is clear that the preliminary testing has been more involved and taken longer than originally envisaged. This is because the overall program has required the main contractor to drive ahead with service installations before it has been confirmed that the basic fabric is airtight.

Other issues have proved to be insufficient site management staffing from the main contractors, leading to delays because some airtightness details, particularly around external doors in the various flats, have had to be modified and resolved on the hoof. We anticipate that this should prove to be a teething problem largely limited to the first block, Terrace A, and from our experience we recommend that anyone involved in similar projects should make allowance for teething problems and the sub-con-

Table 1: The average leakage characteristics of the dwelling were recorded as below. The results show great readings, some almost half of the minimum required by Passivhaus Institute for formal certification.

Airflow @ 50 Pa:		**78.4 m³/hr**
Air Permeability Rate @ 50 Pa:		**0.392 m³/(hr.m²)**
Air Change Rate @ 50 Pa:		**0.434 ACH^{-1}**
	Correlation of results, R^2:	**0.999**
	Slope, n:	**0.89**
	Intercept, C_{env}:	**2.51 m³/(hr.Pa^n)**
Test Parameters:		
	Envelope Area, A_E:	**200 m^2**
	Volume, V:	**180.8 m^3**
	Env. Calc. Prepared by:	**Alan Clarke/ Paul Jennings**

Initial Offset Pressure:	-0.70 Pa	Final Offset Pressure:	-1.70 Pa
Initial Inside Temperature:	18°	Final Inside Temperature:	18°C
Average Outside Temperature:	17.5°C	Barometric Pressure:	101.3 KPa

Design Air Changes:	**≤ 0.6 ACH^{-1} @ 50 Pa**			
Address:	**Unit 2**	**Unit 3**	**Unit 4**	**Unit 5**
Achieved Air Changes, ACH^{-1} @ 50 Pa:	**0.434**	**0.556**	**0.411**	**0.416**
Air Permeability, m^3/hr/m^2 @ 50 Pa:	**0.392**	**0.502**	**0.369**	**0.376**

tractors' learning curve during the initial stages. This must be considered for both contractors who make a positive contribution to airtightness – eg. framing contractors, plasterers – and those who can too easily compromise airtightness – eg. plumbers and electricians.

However, it appears to be a consistent theme on larger Passivhaus projects in the UK – Wimbish, Horsham, and now Sulgrave Gardens and Lancaster Cohousing – that the role of the Airtightness Champion is not well understand by main contractors. The airtightness champion – or the site manager lumbered with that role (!) – needs sufficient time and authority to guarantee the effective communication and co-ordination required to ensure that staff and subcontractors deliver the airtightness strategy within the program. Also on larger projects a single airtightness champion may just not have enough time to oversee the range of site activities that either deliver or potentially compromise airtightness across a range of units in several blocks – and, of course, airtightness champions get sick and have holidays like everyone else. Hence we always recommend training a minimum of 2 airtightness champions, or more on larger projects.

It does also appear that senior staff can be too wedded to the construction program, not appreciating that some airtightness details, especially those buried within the final building structure, have to be completed before moving on. Proving these works by leakage checks or preliminary testing before progressing the build can slow the program, but gives much greater certainty of final success. Unfortunately on occasion the program has overridden even the objections of operatives fitting specialist air-sealing products. Hence the airtightness works may be incomplete or just ineffective – a classic example at Horsham was watching attempts to seal along the wall to floor joint in a puddle – not a recipe for long-term success! Site management need to appreciate that it is much easier and cheaper to get the airtightness right first time. Covering over a compromised air barrier, because the program requires insulation to be fitted, leads to test failures and expensive remedial works.

Another factor experienced at the Lancaster Cohousing project, although to a significantly lesser extent than on an earlier Passivhaus project, (12 houses in Horsham for Saxon Weald HA) is high humidity and moisture levels causing sealing tapes to fail to adhere properly to OSB and other timber surfaces. It appears to be the case that once a robust seal has been achieved, Pro-Clima and similar high-performance tapes, will remain in places, normally only failing due to mechanical damage, a common example being the installation of window cills giving rise to tears in membranes and/or tapes in the corners of window reveals.

However, if timber substrates, such as OSB, are not sufficiently protected on site, they can absorb large amounts of moisture and then take a long time to dry out. When Tescon or a similar tape is applied, it initially appears to stick, possibly even with a primer being utilised. If the tape seal hasn't already achieved a robust adherence, the rise in humidity overnight, as the temperature within the dwelling drops can fatally compromise the tapes' bond to the underlying surface. Such tapes will generally have to be replaced.

So has the airtightness strategy at Lancaster Cohousing been successful? The first acceptance test results can be seen in Table 1 above. The results show great readings, some almost half of the minimum required by Passivhaus Institute for formal certification.

Whilst there has undoubtedly been a huge learning curve on the initial block, Terrace A, we have just completed the acceptance testing of the four houses in this terrace. By the time this article is published, many more units will be complete. Liaison with the key trades affecting airtightness – plasterers, plumbers and electricians – has improved as awareness of the airtightness requirements increases. However, it remains the case that every new operative presents a significant risk, and that the induction of new staff has proved inadequate. Another issue has been failures to pass information within subcontractors, with

Inside view of one bed flat during air test (with staircase to mezzanine bed platform in the open cathedral roof space).

Credits

Client: Lancaster Cohousing represented by Jon Sear as client project manager.
Project architects: Andrew Yeats, Vincent Fierkens & Lucy Nelson of Eco Arc Ecological Architecture Practice.
Project manager and quantity surveyor: David Fotheringham of Turner and Holman.
Structural civil engineer: David Tasker & Gary Willis of Ramboll.
M&E engineer & certified Passivhaus designers: Alan Clarke/Nick Grant.
District heating system designer: Steve Pettit and Rob Clegg of Pettit Singleton Associates.
Passivhaus certifier: Peter Warm.
CSH & Life Time Homes Consultant: Eric Parks.
Main contractor: Graham Bath & Charles Whittle of Whittle Construction.

non-site based senior staff, even when exhaustively briefed on the onerous airtightness requirements for Passivhaus, failing to ensure that the tradesmen and women on site follow the guidance to help us achieve the required airtightness target.

In our opinion, future Passivhaus projects must devote additional resources to repeatedly communicating the requirements for Passivhaus airtightness – planning ahead, following the air barrier strategy, having trained and competent staff, using appropriate products correctly, controlling work's package which delivers the air barrier or which involve penetrations through the air barrier. These efforts need to be concentrated at the start of a project, to propel all site staff up the learning curve, but the airtightness champion must be careful to track personnel changes and ensure that incoming staff do not compromise the airtightness by following business as usual, just doing what they've always done – generally a recipe for Passivhaus failure!

It is also important for main contractors to appreciate the additional demands on site management and adjust staffing accordingly. Stressed site management, making erroneous assumptions about critical details affecting airtightness – for example the positioning of door thresholds – can give rise to test failures, with additional costs and potentially significant delays. It is very easy to make minor savings that give rise to significant extra costs down the track because of airtightness problems – Passivhaus is a premium product, contractors need to respect the demands it places upon them, whether for sufficient and appropriately skilled staff, or for the communication activities necessary to generate a site culture conducive to achieving the onerous Passivhaus airtightness target.

Paul Jennings, Mike Neate and Andrew Yeats

Paul Jennings of GAIA Aldas has 25 years of airtightness experience, originally as a tester but more recently providing consultancy and training to facilitate the airtightness process for Passivhaus and other low-energy buildings. He tested the first certified Passivhaus housing and non-domestic projects in the UK, built by John Williamson in Machynlleth, and has contributed to numerous well known refurbishment projects, including Andy Simmond's Grove Cottage in Hereford (first UK certified Enerphit) and Adam Dadeby's Hunter Moon in Totnes (achieved 0.2 ACH^{-1}@50Pa in the acceptance test). He worked on the multiple-Passivhaus projects at Wimbish, Horsham and Sulgrave Gardens, and is currently carrying out preliminary and acceptance testing of the 44 units of the Lancaster Cohousing project.

Mike Neate of Eco-DC Limited has specialised in the management of bespoke newbuild and refurbishment projects, more recently concentrating on delivering airtightness, including window and door installations. After studying architecture, he lived in Spain for a decade, where he worked on a variety of building projects. On returning to the UK, he continued building and design work on a number of environmentally sensitive projects. With his skills and experience and a committed on-site team, Eco-DC now offers a complete building service, from design through planning, and ultimately construction, to deliver environmentally benign, highly energy efficient buildings.

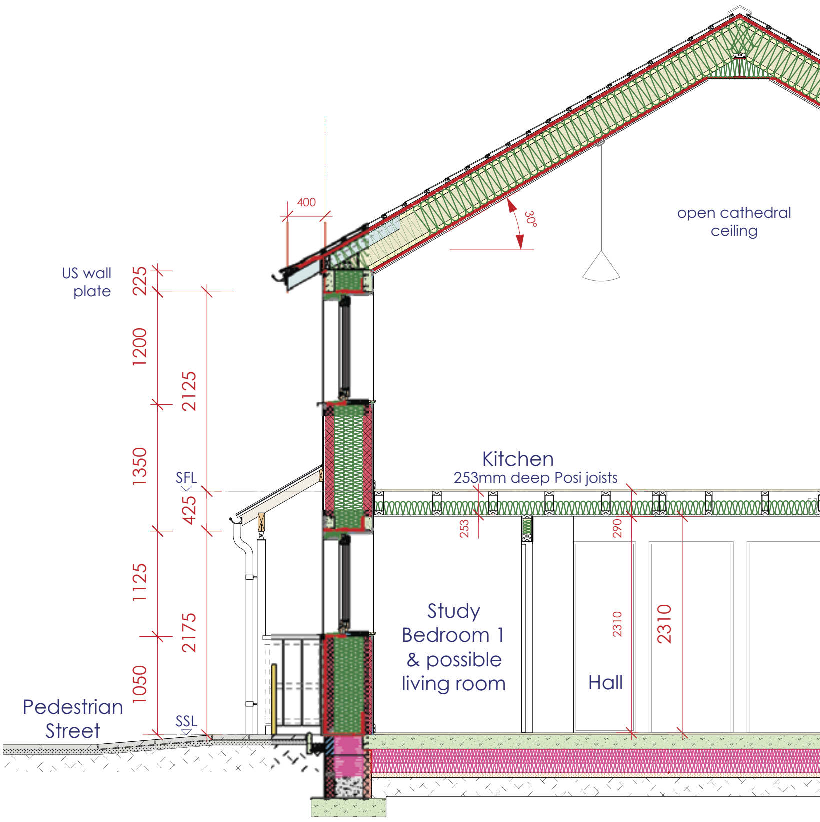
Andrew Yeats (Editor) Eco Arc Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for Cohousing having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years. Andrew has recently as a qualified a certified Passivhaus Designer, having passed the Passivhaus exams following the course hosted by WARM in Birmingham.

Lancaster Cohousing project

(part six)

Lancaster Cohousing Project is a certified Passivhaus/ Code for Sustainable Homes, level 6 and Life Time Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects. Andrew Yeats and David Fotherinham report.

Figure 1. General house cross section drawing of the upside-down living houses with open cathedral ceilings.



Work has now progressed well on site. Individual home owners are starting to move in to the largest certified Passivhaus Cohousing project in the UK, with forty one individual households, ranging from one bed flats to three bed family houses, along with shared community facilities. In this, part six, article we cover an overview of the roof design to Passivhaus standards and we also review the procurement/contract route followed in the spirit of the participatory designed project.

Lancaster Cohousing, from its conception, has aimed to be a cutting edge example of sustainable design and living. The decision to design and certify all homes to Passivhaus standard ensures a rigorous approach to the energy performance of the buildings, with attention to detail to ensure continuity of the insulation zone and elimination of cold bridging at all key junctions (ie. wall to roof).

In previous articles we reviewed the detailing of the ground to floor junction detail (see article 2, vol. 21, 3) Walls, windows and intermediate floor junction details (article 4, vol. 22, 1). In this article we will move on up to discuss the two main roof designs employed. Originally all houses were going to have open cathedral ceilings up to the ridge, using 350mm deep JJI type I beam rafters as shown in Figs. 1 to 5.

The key details to note, that elevate this conventional roof to wall head detail up to Passivhaus standard, include the following:

- Continuity of the 350mm roof insulation zone down to 300mm wall insulation zone, with care taken to ensure the blown in Knauf insulation fully fills the void in the bottom triangle of the rafter foot. The Knauf Perimeter Plus loose Blow-in-System is a 70% recycled glass mineral wool insulation with a thermal conductivity of 0.034W/mK; designed to be blown into timber frame voids through translucent netting from the inside. The 18mm plywood cavity closer at the top of the cavity causes a small cold bridge, but roof fabricators required it to form a strong base to support the bottom edge of the I beam rafter foot.
- 22mm thick Gutex Multiplex sheathing board over-sails the top edge of the I beam rafters to reduce the cold bridge over rafters, and fully supports the Proclima Solitex Plus roofing membrane below the counter battens and tiling battens.
- A continuous seal of Orcon F adhesive fixes down the roof membrane to the eaves SW sarking boards, to prevent wind ingress under the roof membrane in to the insulation zone. In addition a vertical strip of Solitex Plus roofing membrane, or Solitex wall wrap membrane, is brought down from the roof Gutex sarking board and sealed to the top of the external render at the block work wall top to prevent wind ingress at the wall to roof junction (ie. the membrane is dressed down behind the 25x185mm soft wood facia between the exposed rafter feet).
- The sloping ceiling soffit is under drawn with a ProClima Intello vapour control layer/air tightness barrier on 9mm OSB. 25x50 battens form a roof service void for electrical wires etc, to ensure no penetrations are required through the air tightness barrier. The finish to the sloping ceiling is 12.5mm dry-lining plasterboard,

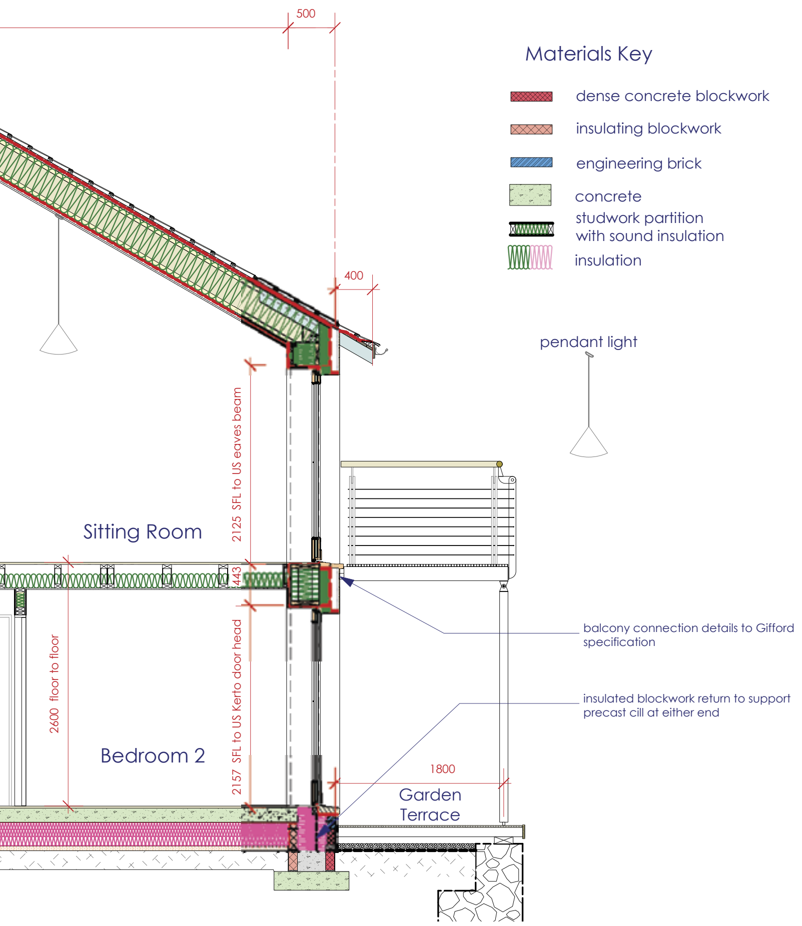


Fig 3. Picture of the 350mm JJI roof rafters delivered to site ready for erection.

with plaster skim finish.

- The critical junction of maintaining the air tightness continuity from the sloping ceiling membrane and wet plaster wall is resolved with a parge coat to the block work wall, overlaid with Contega airtightness tape, with the tape mesh set in to the wall wet plaster and the top sticky edge bonded to the roof Intello vapour control layer.

Due to the pressures of working to a tight/affordable budget and to meet the value engineering targets to get within the 'guaranteed maximum price' of the partnering contract (see below), we reluctantly agreed to have more conventional flat ceiling bob tailed truss rafter roof on many of the houses. Although spatially less attractive it saved

Figure 2. Detailed cross section of the 350mm JJI roof rafter junction with the masonry wall head.

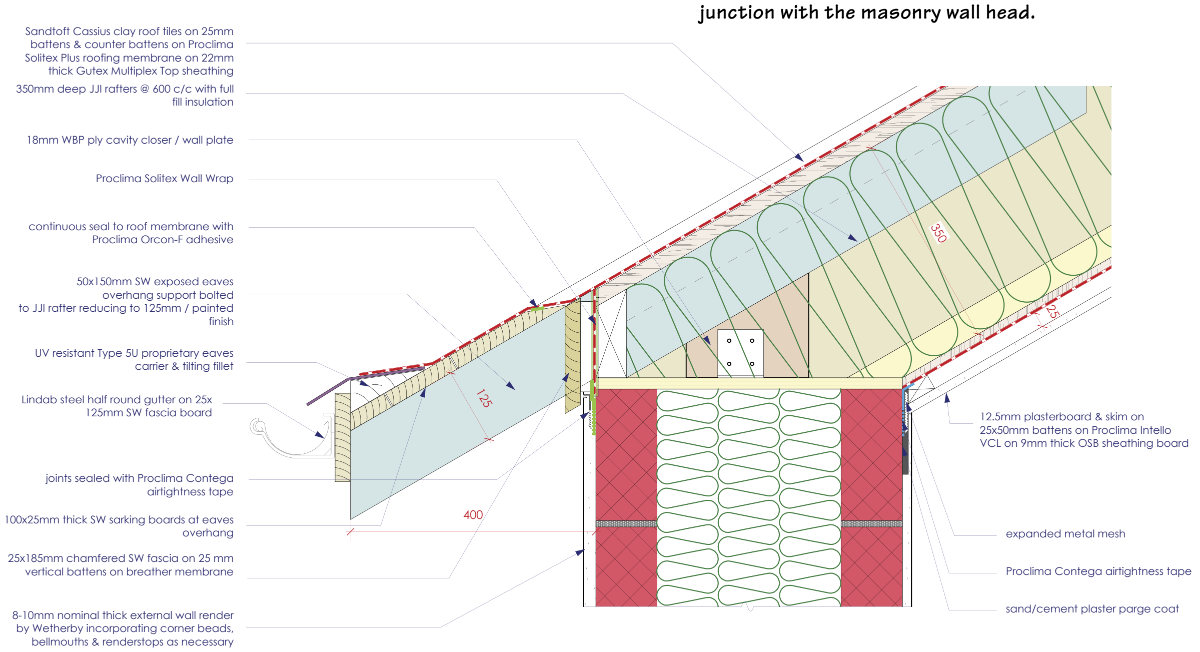


Figure 4. Right: picture of the 350mm JJI roof rafters in place forming open cathedral ceilings.

Figure 5. Below: the finished open cathedral ceiling to an upstairs flat with mezzanine bed platform.

£177K across the project and gave us other Passivhaus advantages of allowing us to increase the roof insulation levels from 350mm blown insulation on the slope to 500mm quilt insulation on the flat and allowed us to remove the plywood cavity closer, eliminating the previous wall head cold bridge. This change also reduced the internal heating volume for the PHPP calculations, and so, over all, in the end, it was a positive change.

The key details to note, that elevate this conventional roof to wall head detail up to Passivhaus standard include the following:

- No cavity closer at the top of the wall to allow continuity of the 300mm wall insulation connecting with the 500mm deep loft insulation. Maintaining thick insulation is aided by the bob tail truss format with an upstand leg, rather than a tight triangle in this location, common with more standard fink trusses.
- A continuous seal of Orcon F adhesive fixes down the roof membrane to the eaves SW sarking boards, to prevent wind ingress under the roof membrane in to the insulation zone.
- Illbruck FM 330 PU air tight expanding foam to the top of the inner leaf block work wall head to the under side of the two 50mm noggins between rafters, combined with Contega air tightness tape sealed to the underside of the same roof noggin, with the tape mesh bedded in to the top of the external render to prevent wind ingress in to roof area.
- The flat ceiling soffit is under drawn with 18mm OSB with Tescon tapped joints as the air tightness barrier. 25x50 battens form a roof service void for electrical wires etc, to ensure no penetrations are required through the air tightness barrier. The finish to the ceiling is 12.5mm dry-lining plasterboard with plaster skim finish.
- The critical junction of maintaining the air tightness continuity from the flat ceiling OSB air tightness barrier and wet plaster wall is resolved with a parge coat to the block work wall, over laid with Contega airtightness tape with the mesh set in to the wall wet plaster and the top sticky edge bonded to the OSB and protected with a batten in the corner.

Both roof details seem to work well, but require careful attention to detail by site operatives to maintain, air tightness inside and wind tightness outside, as the rafter feet project beyond the wall external face. If we had our time again we may be tempted to explore further a detail evolved brilliantly, by Mike Whitfield, whereby the roof membrane is dressed down and sealed to the wall external face, and at a later date projecting triangulated eaves' sprockets are bolted on as an addition.

Both Leeds Met University's initial thermal imaging analysis and Alan Clark's thermal imaging site inspection photos indicate on some houses we have some eaves' wind ingress and some possible gaps in eaves' roof insulation so remedial action is ongoing in this regard to comply with Passivhaus certification requirements.

Procurement methods

Procurement methods and contract administration are not perhaps the most exciting topic for review or to read about, but we do believe it has been fundamental and critical to the success of this ground breaking project. Below we review the procurement options we considered and explain in more detail the procurement mechanisms we adopted.

Figure 6. General house cross section drawing of the bob tailed truss rafter roof with flat ceiling.

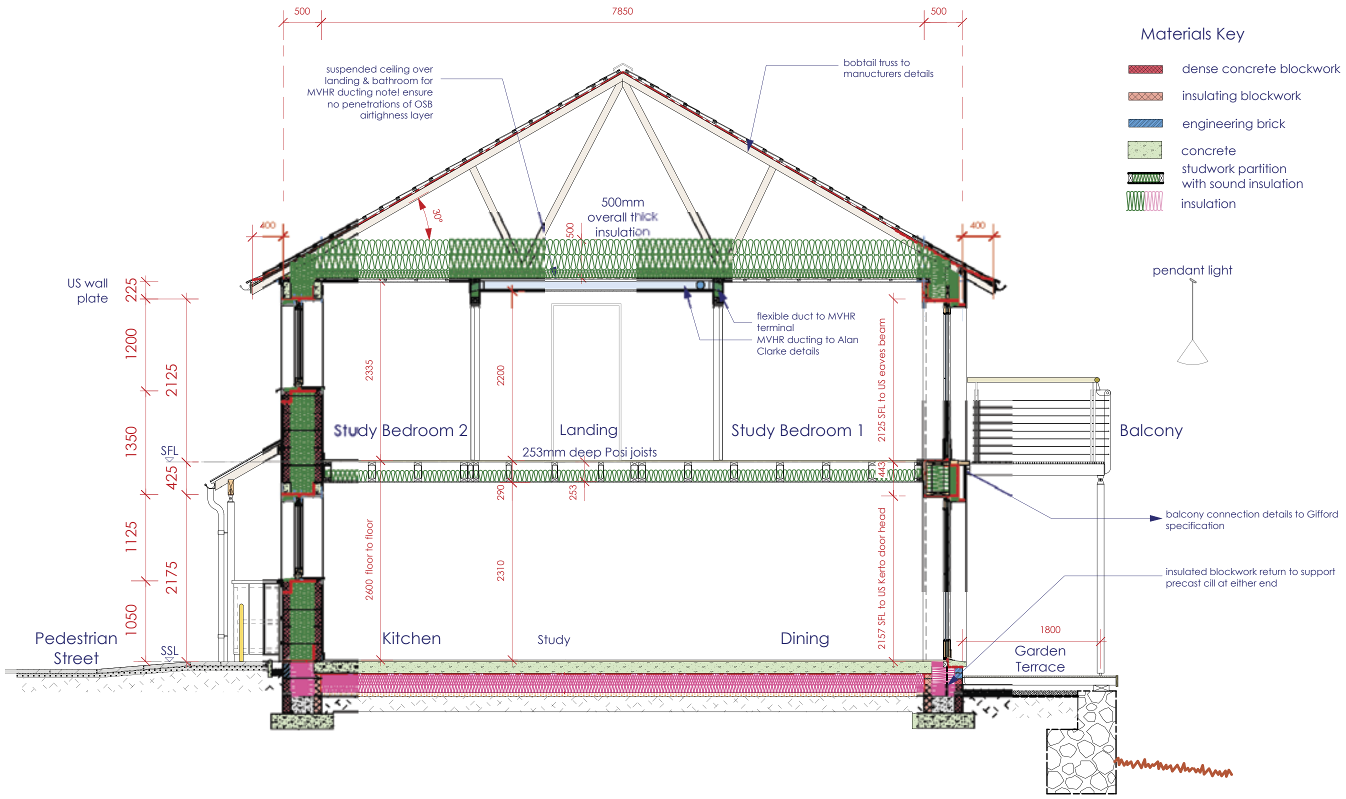
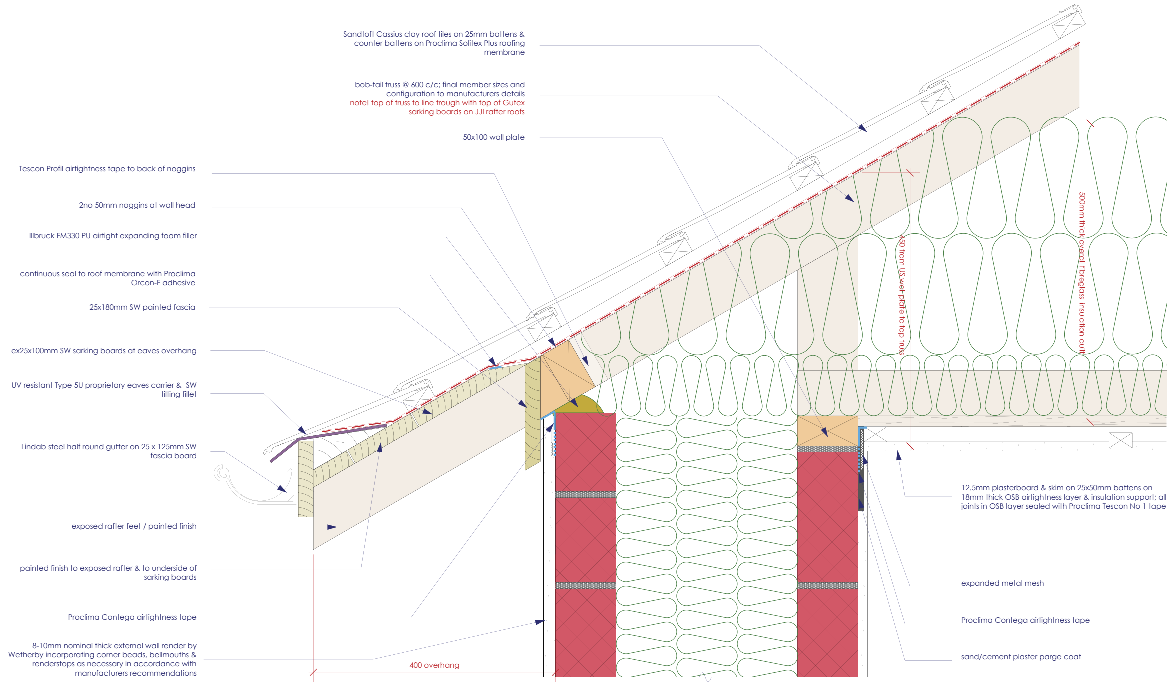


Figure 7. Detail cross section of the 350mm JJI roof rafter junction with the wall head.



Competitive tender

We have frequently used traditional ‘single stage competitive tender’ procurement successfully for complex projects. It does, however, rely on the 'first past the post' principle and on that basis the appointed contractor is not necessarily the most sympathetic one to carry out the project. Traditional procurement does provide the maximum control over design and ultimate quality of the work, which is important. With the project at Lancaster Cohousing, including many non-standard Passivhaus details and complex civil works, it was decided there would be significant risk pricing by contractors, and possibly some difficulty in achieving the most competitive tenders, or some reluctance to tender. We were also mindful of

Figure 8. Right: picture of the eaves' detail, with Solitex Plus roofing membrane, overlaid with counter battens and tiling battens. A more durable eaves' carrier terminates in to the gutter below the bottom tile.

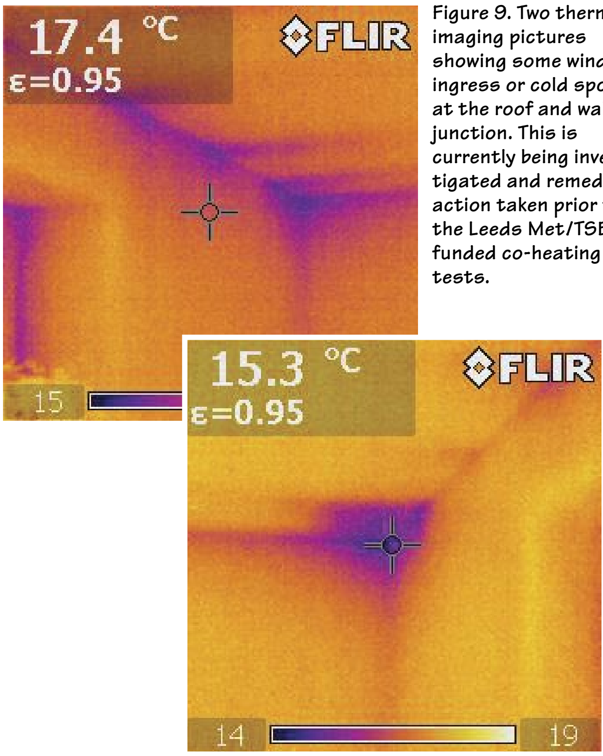


Figure 9. Two thermal imaging pictures showing some wind ingress or cold spots at the roof and wall junction. This is currently being investigated and remedial action taken prior to the Leeds Met/TSB funded co-heating tests.

potential extra claims throughout the contract period.

Design and build:

Whilst we have utilised design and build contracts successfully on a number of occasions they are usually for relatively simple projects, by comparison with the proposed Lancaster Cohousing development. With design and build there is always a loss of a certain amount of control over the final design and quality of the project that would be delivered and we decided this would be a very undesirable aspect at Lancaster Cohousing. With design and build the possibility of risk pricing, in respect of some of the more complex elements of the project, would be great and certainly more than might apply if traditional procurement was adopted. Design and build could have resulted in an earlier commencement of the works on site than might otherwise be the case, but we decided if other contract arrangements were carefully structured, the difference in timescale would hopefully be negated.

Partnering

Partnering involves selection of contractors at an early stage, on the basis of a combination of price and quality. It hopefully provides for the most informed choice of contractor, who is sympathetic with the ideals of the project but able to deliver the right project at an economic price. There are a wide variety of ideas as to what partnering comprises. It can range from early selection of a contractor with whom to negotiate a traditional contract, on a two-stage approach, to guaranteed maximum price partnering contracts with shared incentives between the contractor and employer for dealing with savings. With either of these options the contractor is selected on a combination of price and a quality appraisal. If the latter option of guaranteed maximum price and shared savings is adopted, there are at least two forms of contract that can be considered. If a partnering approach is adopted the process of contractor selection and development of the contract can commence as soon as there is sufficient information to enable contractors to form a reasonable opinion regarding the scope and nature of the project. This will often be achieved at about the stage when the project is submitted for planning approval (Stage D/E).

Partnering contracts are generally used for projects where it is considered beneficial to establish early and close relationships with a contractor to undertake a project, with the benefit of potential contractor input into the design process and a better understanding of the project. Partnering contracts normally involve a two-stage contractor selection process, with initial selection of the preferred contractor and then, after a period of design development, negotiation of a stage 2 definitive contract.

Why we chose partnering for Lancaster Cohousing

There are a number of circumstances where partnering contracts are considered beneficial, and the reasons we opted for this choice at Lancaster Cohousing are as follows:

- The project was complex in nature, where early contractor input, as part of the design team, has been considered beneficial.
- The project was to involve unfamiliar Passivhaus systems and renewable technologies where, without a partnering approach, there would potentially be extensive risk pricing by contractors.
- The project scope of works was difficult to quantify (particularly civil works) at the tender stage, and a

Figure 10. Picture of the no car/pedestrian access street to Terrace A, where the first home owners have moved in.

structure for valuing the works needed to be set up as part of the tender process.

- The project was on a tight timescale where there was a need to achieve early contractor selection and commencement of the works.
- We simply wanted to avoid first past the post contractor selection and a possibly more adversarial approach to contracting.

Our view was that it would be extremely unwise to adopt design and build as the procurement option in this instance. It would have been nigh on impossible to have progressed this project under normal single stage competitive tender processes, as it would have been very difficult at the outset for any inexperienced contractor to accurately price a large Passivhaus project, with 41 individual house holders on a complex site, which was partly contaminated/brown field site on a steep slope down to the river. We agreed that the favoured option would be a partnering approach, with a guaranteed maximum price, with a shared incentive for savings.

Outline strategy of partnering at Lancaster Cohousing Project

A partnering contractor (Whittle Construction) was selected through an initial tendering process. That process was set up relatively speedily and involved contractor selection on the basis of a combination of a limited pricing submission, quality submission and interview. After selection as preferred Contractor, Whittle Construction worked with the project design team from planning application stage through to start of works on site as part of the stage 2 process, but it was not a contractually binding appointment.

Whittle Construction worked with the design team over this period, pricing the work's packages and assisting with value engineering to adjust the project to achieve the guaranteed maximum price. As a satisfactory guaranteed maximum price was achieved, Whittle Construction was then appointed formally as the building Contractor.

The initial arrangements for this two stage partnering approach are similar to those for the traditional contract, but use a building contract and procedures which incorporate partnering provisions. (ie. NEC3 Engineering and Construction Contract Option C: Target Contract with Activity Schedule.) In utilising the NEC contract a guaranteed maximum price was established for the works, Whittle Construction are then reimbursed on the basis of actual costs incurred on site, plus their competitively priced preliminaries and overheads.

The contract does, however, incorporate a target cost and if there is a saving relative to the target cost, that saving is shared between the contractor and the employer, in this instance on a 75:25 basis (often 50:50 provides the basis). If the final cost is between the target cost and the guaranteed maximum price the contractor is reimbursed his actual costs. If the cost exceeds the guaranteed maximum price the reimbursement to the contractor is capped at the amount of the guaranteed maximum price, subject to any variations issued to Whittle Construction during the contract, which give rise to adjustment of the guaranteed maximum price being required. >>>

Figure 11. Main picture is of the south facing garden and first floor balconies over looking the River Lune at Terrace A, where the first home owners have moved in.

Figure 12. Inset: picture of shared common house kitchen/dining area, with open cathedral ceiling.

During the construction process Whittle Construction have been carrying out the works and at all times been liaising with the other parties regarding the costs of individual activities being undertaken. Whittle Construction are reimbursed on the basis of the actual costs incurred, plus the pre-agreed preliminaries and overheads. That reimbursement is subject to the limit brought about by the guaranteed maximum price. The process ensures that competitive tendering of individual activities can still continue and achieves a potential shared benefit between the contractor and employer in instances where savings can be achieved.

We have found that adopting a partnering approach of this nature achieves a significantly closer working relationship between the contractor and the project team, often in a more harmonious way. The partnering process, prior to commencement of works on site, took nine months. In the meantime all the team members got to know each other well and knew how each worked and interacted with one another. We have discovered that the entire project team (client, designers, managers and contractors) have appreciated the partnering approach to contracting at Lancaster Cohousing and believe it has been beneficial, if not fundamentally critical, to the success of this ground breaking project.

Andrew Yeats and David Fotherinham

Andrew Yeats Eco Arc: Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for Eco Cohousing having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years. Andrew is a Certified European Passivhaus Designer (CEPH) having taken the AECB CarbonLite Passivhaus Design Course & Passivhaus exams hosted by WARM in Birmingham.

David Fotheringham is a project manager and chartered quantity surveyor with Turner & Holman. He particularly appreciates the true cost implications of sustainable design and has extensive experience of various procurement routes, including several previous Eco Arc projects using the NEC partnering contract. David has extensive experience as a charted quantity surveyor and project manager, which has been invaluable in successfully steering this project through the complex design process, procurement, value engineering and contract administration of the on going site works.

Credits

Client: Lancaster Cohousing represented by Jon Sear as Client Project Manager

Project architects: Andrew Yeats, Vincent Fierkens & Lucy Nelson of Eco Arc Ecological Architecture Practice

Project manager and Quantity Surveyor: David Fotheringham of Turner and Holman

Structural civil engineer: David Tasker & Gary Willis of Ramboll

M&E engineer & certified Passivhaus designers: Alan Clark/Nick Grant

District heating system designer: Steve Pettit and Rob Clegg of Pettit Singleton Associates

Passivhaus certifier: Peter Warm of WARM Low Energy Building Practice.

CSH & Life Time Homes Consultant: Eric Parks

Main Contractor: Graham Bath & Charles Whittle of Whittle Construction.

Lancaster Cohousing project

(part seven)

Lancaster Cohousing Project is a certified Passivhaus / Code for Sustainable Homes, level 6 and Life Time Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects. Work has now progressed well on site. Individual home owners are moving in to the largest certified Passivhaus cohousing project in the UK, with forty one individual households ranging from one bed flats to three bed family houses, along with shared community facilities. Gary Willis, David Tasker and Andrew Yeats discuss the civil and structural challenges ...

In this, part seven, article we cover an overview of the brown field site/civil engineering works that underpins the Passivhaus designs.

Civil engineering challenges

Even by brownfield site standards Halton is pretty exceptional and on a small plot of land we find contamination, flood risk, unstable soil and rock faces and variable geology in abundance. Green, sustainable design is usually focussed on the visible building superstructure. For a building project to be truly sustainable all aspects need to be considered with a view to reducing environmental impact and enhancing social impact. Ramboll was appointed by the client to address these sustainability issues for the key civil, structural and environmental engineering aspects of the project.

Understanding the Site. The site was green field land until Halton Mill was constructed between 1847 and 1891 and contained substantial buildings, together with a mill race running through the site leading to a mill pond. The steeply sloping rock and soil faces to the River Lune were terraced to accommodate the large buildings by quarrying the rock face, or constructing stone and brick retaining walls up to 10m in height. The mill produced oil cloth, a waterproof material for which Lancaster was well known. It involved treating material with a range of lead and mercury based

Figure 1. Fantastic views from the site across the River Lune.

resins and dyes. Use of the mill started to decline in the 1950's and, in the 1980's, many of the buildings were demolished, with the site becoming thickly overgrown with vegetation.

The site investigation confirmed a highly variable geology, with varying depths of made ground (demolition materials) over a mix of alluvium, gravels and clays over sandstone bedrock. The challenge was to determine any pattern to the results - which could vary significantly within a few metres. Whilst the demolition had occurred only a few decades ago, the best record available was an amateur video taken by canoe enthusiasts, which showed glimpses of the demolition occurring in the background.

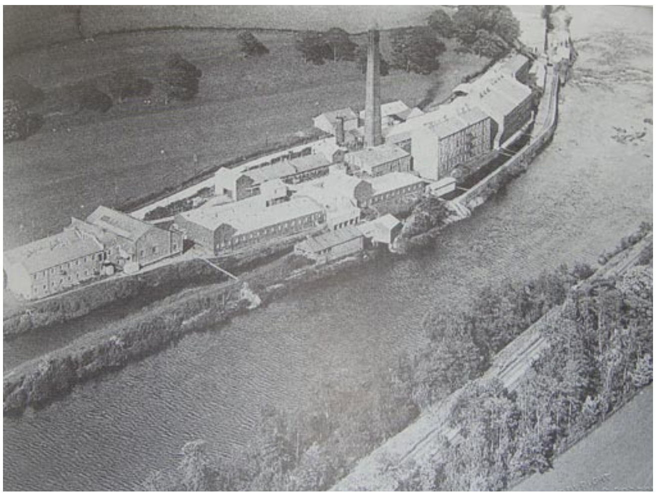


Figure 2. Aerial view of the former Halton Mill, showing the extent of buildings. Most have been demolished but some remaining today.

Contamination. Following extensive site testing this was found to be at low levels within the made ground throughout the site – but more significantly in traces of lead and mercury from the oil cloth manufacture at the surface and on the river banks, with localised ground gas associated with the in-filled mill pond. Successful mitigation of contamination requires a thorough knowledge of the site, an understanding of its end use, and a clear strategy in order to achieve appropriate solutions. The solution involved a capping

Figure 3. View of the site taken from the canoe videos showing the former mill during demolition showing the scale of the construction and the possible retaining walls that could be present on site

technique providing a barrier to the contaminated soil and gas. This was particularly appropriate at Halton as the density of buildings with their solid ground floors and hard-standing could provide this barrier for most of the site. Importantly, this minimised removal of material from site with the associated environmental impacts. The partial handover of the part remediated site proved particularly problematic and required rigorous site and construction management.

Balancing cut and fill. It is always good sustainable design practise to balance cut and fill and moreover, usually financially advantageous. Where the ground is potentially contaminated, as was the case with Halton, this is of paramount importance. Working within level constraints, and, in particular, those from flood mitigation, the proposed site design was assessed to ascertain volumes which included the use of hardcore from crushed brickwork from site demolition. With the final completion of the ground works a slight surplus of material remained, suggesting that floor levels could have been raised. However, this would have resulted in higher retaining walls, with a questionable financial outcome.

Figure 4. View of the site immediately before redevelopment with some buildings remaining. The site was re-graded and significant vegetation is still present

Tackling the slopes. Forming the level terraces for the buildings required slopes to be formed between 45-55 degrees (from the horizontal), retaining walls between 2-7m high, and the exposed rock face to be made stable. Our aim was to determine the most environmentally sensitive solutions to these situations and generally this involved techniques other than conventional steel or reinforced concrete structures. The required slope angles exceeded the natural characteristic slope of the soils, hence some form of ground engineering was required. Soil nailing or rock anchoring (pinning the face of the soil back to the body of the soil or the rock at depth) were considered in detail, but the variable nature of the ground gave concerns regarding what could be encountered during the work. The preferred solution was reinforced earth, with the ground excavated, replaced and compacted in conjunction with a geo-synthetic net. This allowed any underground features to be exposed and dealt with and the variable nature of the ground fully understood during excavation, with any poor material removed or the geo-textile arrangement adjusted if required. The challenge was to use the 'poorer' clay soil occurring on site, rather than to remove it and import a more typical and preferable granular material.

Figure 5. Excavation, revealing the former rock face beneath the existing ground surface representing the rear elevation of a former mill building that occupied the site.

The range of retaining wall solutions considered included timber and concrete crib-lock walls, together with traditional concrete and masonry gravity construction. From a review of both cost and sustainability, gabion baskets, filled with natural rock or demolition arisings, were selected as the preferred option.

Whilst a significant amount of rock was excavated during the works to shape the site and install the drainage, the logistics of crushing & grading this on site as a gabion basket infill material proved cost prohibitive, and the counter intuitive solution of importing a basket infill stone adopted. This is one of many situations where the balance

Figure 6. Typical cross-section of the reinforced earth slope above a rock face detailing the layers of geo-synthetic grid and the anti-erosion matting to the face.

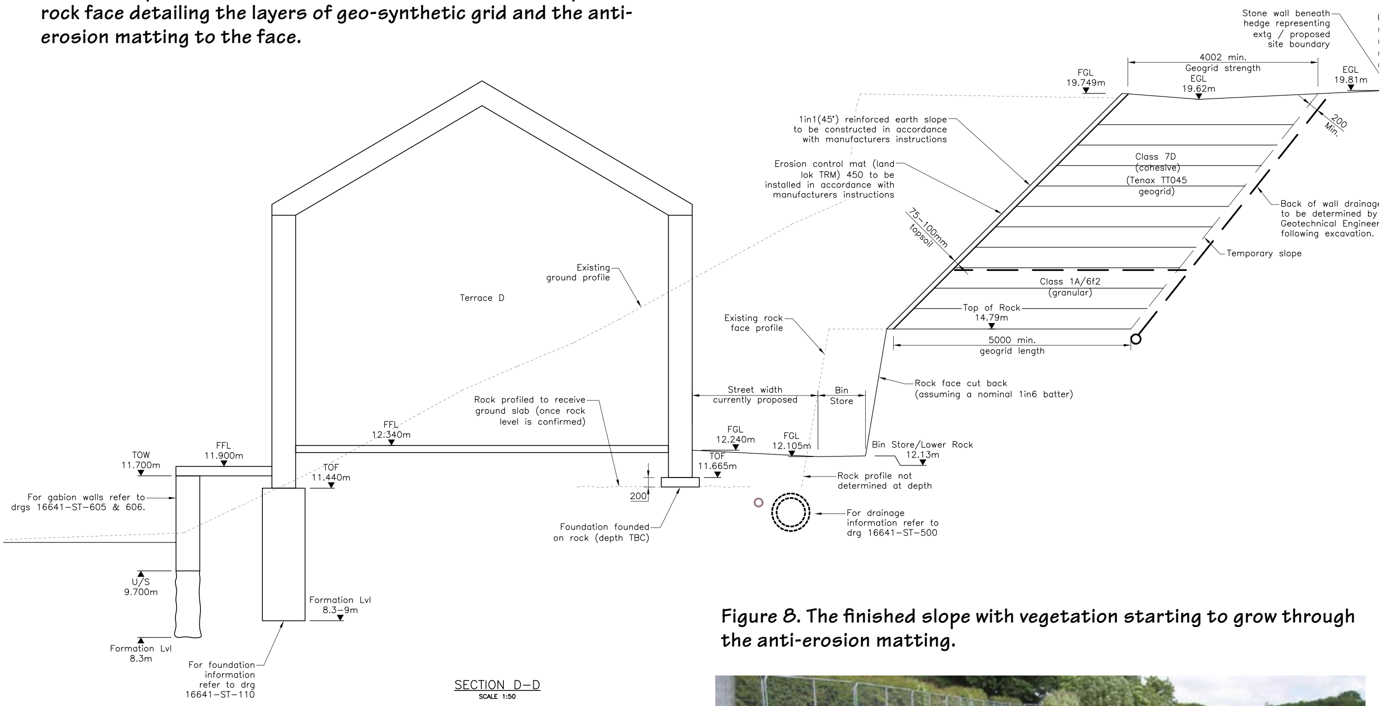
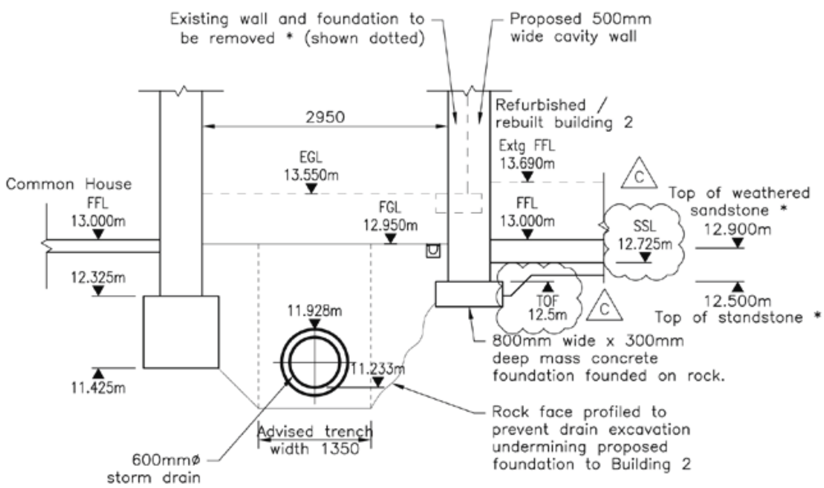


Figure 8. The finished slope with vegetation starting to grow through the anti-erosion matting.

between commercial and sustainable criteria is difficult and precarious. For the tallest of retaining walls, of up to 7m maximum height, a combination of a gabion facing tied back to a reinforced earth block was developed, again using the site-won clay as the fill material behind the wall. Despite the disappointment of importing stone for these gabions, the solution was still preferable in environmental terms to reinforced concrete, was preferred visually by the residents and was of the lowest cost.

Flood mitigation and underground drainage strategy. The whole site lies within a flood zone 3 - a high risk, 1:100 probability of a serious flood event. The design objective was to ensure that all habitable dwellings fell within a flood zone 1 - a low risk, 1:1000 probability, thus achieving maximum credits from the Code for Sustainable Homes. To achieve this required extensive river and catchment modelling, which incorporated a 20% allowance for climate change and a 600mm freeboard to allow for modelling uncertainties. This placed the finished floor levels some 2.00m above the top of the river wall and general site level.

Figure 7. Typical cross-section through the pedestrian street showing the over-sized pipe providing attenuation storage coordinated with adjacent foundations to avoid undermining them.



In order to maintain the best possible sustainable approach, storm water run-offs were to be reduced to that of a greenfield site – extremely onerous when most of the site contains building footprint and where the remainder is either steeply sloping or land subject to flooding. The solution was to significantly restrict storm water discharge from the site and use 600mm diameter 'over-sized' pipes running underneath the narrow pedestrian street to act as a reservoir, in combination with localised areas of off-line

Figure 9. Gabion wall to the front of the terraces (with pipes built in to the top sections to receive the handrail uprights).

underground storage via proprietary 'crate' tanks within a waterproof membrane.

The idyllic nature of Halton on the River Lune belies the fact that it contains a plethora of environmental and geological hazards. Whilst brownfield sites are espoused, and quite correctly, as being the 'must have' for a truly sustainable building project, the reality is that they present challenges that can form key constraints to design development and result in financial and programme risk. We believe that at Halton, a rigorous design approach between contractor, client and design team has delivered a low impact, environmentally sensitive response to extremely challenging site conditions.

Structural challenges

The buildings. This was an opportunity for new structural approaches. This project gave us the opportunity to rethink the design and construction of low cost, low rise housing to Passivhaus standards. Over the years we have engineered many innovative housing schemes, from timber frame/ timber 'I stud' construction to more recent projects involving very wide cavity masonry and cross laminated timber. Our pre-conception was to develop an off-site, prefabricated timber panels system for walls, floor and roof, keeping the construction dry and minimising construction times on what is a restricted and difficult site. However, the very tight cost parameters dictated that of the many alternatives we assessed, concrete block cavity construction was consistently costed preferentially to the offsite timber solutions. It would seem that main contractors appreciate the control which comes from using local bricklayers and materials. Even the south facing terrace walls, with their large openings, could not justify an off-site prefabricated panelled approach on cost grounds. Whilst this was disappointing from a strictly parochial engineering viewpoint, the use of tried and tested low risk technology, on what is a very problematic site, has considerable sense and logic to it. The innovation in this scheme is centred more on the very close attention to detailing and bringing together of standard components than on new conceptual structural systems.

Foundations. Cost is generally the main design driver for foundation design and, with a few exceptions, the terraces have very simple, straightforward, concrete strip foundations and ground bearing slabs. Competent bearing strata in the form of gravelly sands and clays occur within 0.5m to 3m of the proposed surface, beneath a variable depth of poor quality made ground and simple strip footings allow the variability of these ground conditions to be accommodated. This allows for the foundation and hence the volume of concrete to be optimised for each location. Where the formation depths were greatest (nearly 3m in depth at the extreme eastern end of the site), alternative solutions (mini-piles) were explored, but as these areas were only localised, continuing with a consistent solution was preferred.

Ground slab. The underlying made ground was a variable mix of both granular and cohesive areas, and was not directly suitable for supporting a ground bearing slab. Rather than incur the cost and air-tightness challenges of a suspended slab, we opted to process the granular material by removing large boulders and demolition fragments and compacting the material using the Highways Agency's specification. For the slightly contaminated clay which is not generally used

Figure 10. Typical strip foundation and ground slab detail.

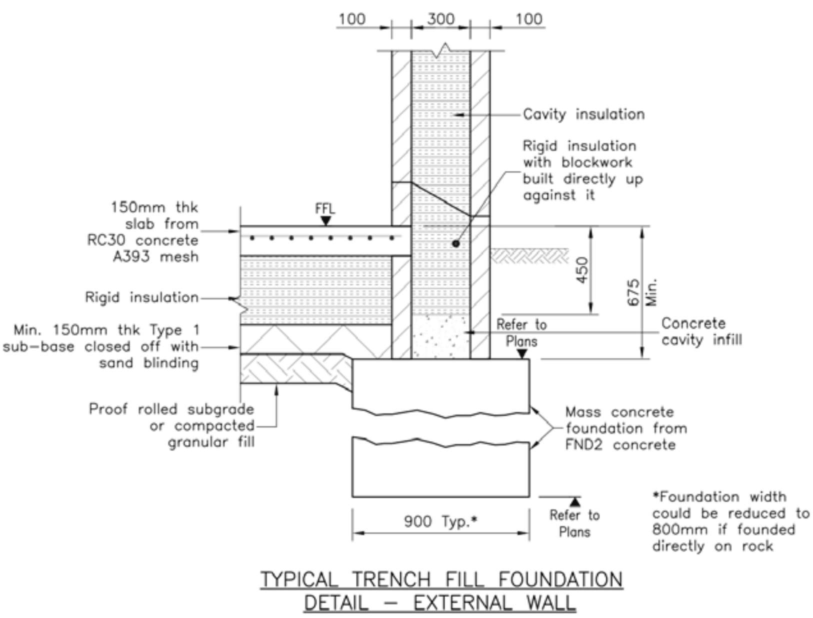


Figure 11. Compaction trials to determine the appropriate plant, number of passes and degree of vibration to compact the site-won clay up-fill material.

Figure 12. South elevation showing Kerto timber framed openings between Block work return walls at the end of party walls.

as a 'fill' material on building sites (being deemed to be unworkable), we again used specialist highway engineering techniques - protecting stock piles from the weather, together with a close monitoring of the moisture content of the clay fill and the implementation of an optimum compaction regime. This effectively saved the expensive and undesirable export of clay from the site, as well as the need to import granular fill. These techniques were used both where floor levels were at existing ground levels, and where floor levels were to be elevated to 3m above river flood levels.

Recognising the potential for some long term consolidation in the up-fill material, thereby causing issues to both finishes and airtightness, the ground slab was formed into the inner leaf of the perimeter walls, providing nominal support to the slab. This unfortunately necessitates the use of mesh reinforcement, albeit lightweight and nominal. Low conductivity thermal blocks were used at these slab supports, avoiding a cold-bridge to the slab.

The concrete specification encouraged the maximum use of cement replacement products (PFA & GGBS), together with the use of the lowest strength concrete appropriate. Recycled aggregates within the concrete were also permitted but the only source was from such a distance as to render their use on energy/carbon criteria self-defeating.

Walls. All external and party cavity walls, excepting the south, were constructed with 100mm leaves of 7N Eco Block containing a minimum of 80% recycled aggregates. The rigorous use of the Buildings Regulations 'deemed to comply' details (Approved Document A, Section 2C) were adopted where possible, which draws from the experience of what works 'in the real world', rather than what can be demonstrated via strict calculation. With much of the blockwork close to its structural capacity, site quality management is essential.

Where external walls did not comply with Building Regulations, the effect of buttressing from the internal walls was included to minimise the use of wind-posts, only utilised in the gable end walls. Even the 18mm plywood boxed cavity closer to window and door openings was included within the modelling of the panels. Structurally, plywood reveals which spanned the full width of the wall were desirable, but this was not ideal from a thermal

Figure 13. Timber ledger supporting eco-joists secured to the wall with resin anchors to maintain the air-leakage barrier.

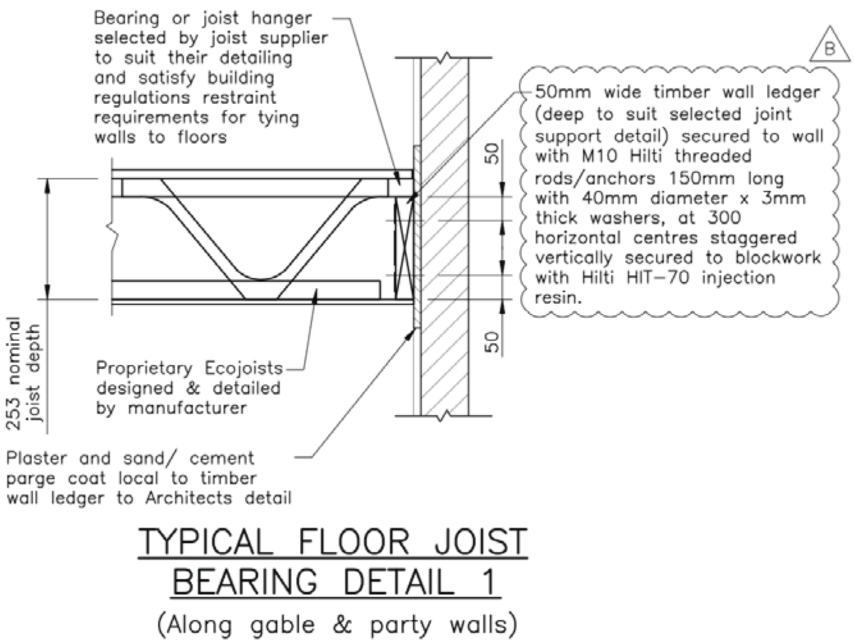


Figure 14. M&E installation integrated through the webs of the eco-joist suspended floors.

performance perspective. A compromise was struck, with windows using half-depth plywood reveals, and door openings using full depth plywood.

Because the air tightness barrier was the plastered inner blockwork leaf, the potential for shrinkage cracking was unacceptable and the inclusion of an air-tight movement joint effectively impossible to detail. Movement joints were therefore included in the outer leaf, as normal, with steel bed-joint reinforcement selectively used in the inner leaves to control cracking, removing the need for joints.

The large openings in the southern elevation dictated that a masonry solution was not viable as this would effectively be a framework of wind-posts, with narrow piers of non-structural blockwork. A Kerto frame was adopted on account of its dimensional stability, predictable structural characteristics and ease of site connections. The main contractor preferred to site fabricate and assemble this, in preference to an off-site panel solution.

Floors and roofs. Metal web eco-joists are a particularly appropriate floor solution as they are not only structurally efficient but allow the passage of air ducts in the structural zone; spanning between a timber ledger secured to the faces of the party and gable walls with resin anchors, compromise to air tightness is avoided. The terrace roofs generally use proprietary timber trusses which still represent the lowest cost solution for domestic houses.

Postscript

Passivhaus has clearly provided a leap in the continuing quest for a truly sustainable future. With the dramatic reduction in energy use for heating and lighting, the specification of building and structural materials becomes significant. Sequestered carbon criteria may now be more important than embodied energy which will inevitably cause a greater attraction towards locally grown bio materials – of which timber and hemp are the obvious example. The quest continues!

Gary Willis, David Tasker and Andrew Yeats

Credits

Client: Lancaster Cohousing represented by Jon Sear as Client Project Manager .

Project architects: Andrew Yeats, Vincent Fierkens & Lucy Nelson of Eco Arc: Ecological Architecture Practice.

Project manager and quantity surveyor: David Fotheringham of Turner and Holman.

Structural civil engineer: David Tasker & Gary Willis of Ramboll.

M&E engineer & certified Passivhaus designers: Alan Clark/Nick Grant.

District heating system designer: Steve Pettit and Rob Clegg of Pettit Singleton Associates.

Passivhaus certifier: Peter Warm of WARM Low Energy Building Practice.

CSH & Life Time Homes consultant: Eric Parks.

Main contractor: Graham Bath & Charles Whittle of Whittle Construction.

TSB building performance evaluation: Prof Fionn Stevenson of University of Sheffield.

TSB building performance evaluation: Dr David Johnston of Leeds Metropolitan University.

David Tasker is a chartered structural engineer. For many years he has been trying to understand life and the meaning of sustainability. Just when he thinks he's there, and completes a successful project, it appears that either the world around has changed or that within has changed. However, he remains steadfast, resolute and enthusiastic.

Gary Willis is chartered structural engineer with over 25 years' experience working for Gifford, now part of Ramboll UK. During this time he has worked on a wide range of projects, in most market sectors via many procurement routes. He Therefore has a detailed knowledge of a wide range civil and structural engineering aspects. His passion is the refurbishment of existing buildings, recognising the sustainability benefits this can bring. He is currently seeking Conservation Accreditation (CARE registration) reflecting his extensive work on historic buildings. Gary has been involved in both the concept and detailed design of the Lancaster Co-Housing project.

Andrew Yeats (Editor) Eco Arc: Ecological Architecture Practice is project architect and lead design consultant. Andrew has a passion for eco cohousing having visited similar projects in Denmark, Sweden, Norway and the US as part of the Winston Churchill Fellowship and having been the resident architect at the Findhorn Eco Village Project for many years. Andrew is a certified European Passivhaus designer (CEPH) having taken the AECB CarbonLite Passivhaus Designer Course & Passivhaus exams in Birmingham.

Lancaster Cohousing Project. (Part 8)

Post Occupation Building Performance Evaluation.

Lancaster Cohousing Project is a certified Passivhaus / Code for Sustainable Homes Level 6 and Life Time Homes, affordable community housing project, which has evolved through a participatory design process with the individual householders and Eco Arc Architects.

Most of individual home owners have now moved in to the largest certified Passivhaus Cohousing project in the UK with forty one individual households ranging from one bed flats to three bed family houses, along with shared community facilities. In this 8th article in the series, we look at key results from the Technology Strategy Board Building Performance Evaluation project undertaken by Lancaster Cohousing Project in collaboration with The University of Sheffield, Leeds Metropolitan University and Closed Loops Projects. The six month research programme, completed in March 2013, consisted of a number of closely interrelated studies comparing design intentions against actual performance during the initial occupation stage of the development.

Picture1: Typical view of the completed Passive houses & the Common House Community Terrace

Occupant Feedback

The University of Sheffield undertook a series of studies which examined occupants' initial experiences of living in the new development, evaluating the usability of key controls as well as the guidance given on how to operate their new homes.

The Usability Study

The usability evaluation involved a walk-through review of the heating and hot water controls, MVHR controls, electrical equipment controls, kitchen appliances, external skin 'touch points', water services controls and other miscellaneous 'touch points' encountered in the most common house type in the development. We adopted six usability criteria as set out in The Building Controls Industry Association (BCIA) *Controls for End Users* guidance document (see figure 1).

Description and location					
Indirect Powerflow 2000 dual thermostat in the cupboard under the stairs					
Usability criteria	**Poor**				**Excellent**
Clarity of purpose	(red)				
Intuitive switching			(yellow)		
Labelling and annotation	(red)				
Ease of use				(green)	
Indication of system response	(red)				
Degree of fine control				(green)	

Comments
An educated guess suggests this is the temperature control for the hot water cylinder immersion heaters but it is not labelled. The right hand knob is easy to operate and work with a good degree of fine control if you know what it is for. The function of the smaller knob to the left is unclear and uncalibrated. There are no indication lights to inform the user the system is on or off.

Figure 1: Typical review of control interfaces table – boiler control

The usability of the heating and hot water controls was found to be counter- intuitive and needed better instructions on how to use them properly. Identifying and labelling switches would improve usability from a resident's perspective. People will naturally want to tweak the system and so either demonstrating the most efficient way to run the heating and hot water system would be beneficial. The MVHR programme controls were found to be clear, easy to understand, quick to follow and well located in the kitchen (Figure 2). Whilst the system counts down days to a filter change, it cannot detect a clogged filter before this date. This is a critical issue for the industry because clogged up filters can drastically reduce air flow as well as forcing the fans to use more energy in order to try and meet the air flow demand.

Description and location					
PAUL coloured TFT touchscreen panel on the wall in the kitchen next to the stairs					
Usability criteria	**Poor**				**Excellent**
Clarity of purpose				(light green)	
Intuitive switching					(dark green)
Labelling and annotation					(dark green)
Ease of use					(dark green)
Indication of system response					(dark green)
Degree of fine control				(light green)	

Comments
The fan annotated imagery makes it clear the unit is related to the ventilation system, although it does not explicitly state it. The touchscreen panel is easy to use and highlights an option or setting when pressed. An orange question mark button offers help and information about the various settings when touched. In the corner is a countdown to when the filters need changing. This is a user-friendly interface for a complicated system but it gives quick access to the essentials easily, offers help when needed and can be fine tuned by those who want to, if they feel they need to. It is worth noting that the date and time have not been correctly set on the unit, unlike the heating and hot water controls.

Figure 2: The MVHR programmer was easy to understand but does not alert the occupant to blocked filters.

Generally the doors worked well in the development, with good movement and balance. The window design was not particularly user friendly and this could potentially undermine the low energy strategy if windows are not opened or closed properly (Figure 3). The MVHR system installed does not have a summer by-pass mode which may cause overheating of the homes in a warm summer, unless residents are encouraged to open the windows in the summer evenings to night purge their homes. As the demand for more high performance windows increases the heavier windows can be harder to control for residents, particularly the elderly, unless the hinge, handle and lock mechanisms are more robustly designed – a challenge that some manufacturers have yet to meet.

Figure 3: Windows locks and handles were fiddly with no fine control adjustment

The WC dual flush nature of the cistern had a counter intuitive flush mechanism (a short push for full flush and a long push for a short flush!) which undermined its good intentions.

Home User Guidance

There was a very informal handover procedure with queries answered on a continual basis. A unique feature of this co-housing development is that residents effectively teach each other how to use their homes on a collective learning basis. The building services team were volunteer residents who happen to be technically able resulting in a very fast response to any issues arising. Care has to be taken, however, that the building services team is not exhausted and that this role is perhaps rotated in the future. The procedure does not yet formally take account of future residents, however, who will also require similar demonstrations and guidance.

There was extensive information in the home user guide, which was usefully linked to web references. The excellent home demonstrations given could be usefully videoed and added to this electronic guidance. Websites and e-documents have many advantages as information can be easily navigated. However, consider the occupant who wakes up in the morning to a breakdown in the heating system due to a power cut. A website may be no use at this point, especially without a charged smart phone. It is probably more robust to have combination of electronic and physical information and the study has recommended laminated instructions are placed next to key equipment, in case of failure.

BUS questionnaire

A Building Use Studies (BUS) survey was undertaken between 28 January and 13 February 2013. 36 responses were obtained out of 36 questionnaires delivered (100%). Overall, the results produced were excellent. Residents were very positive about this development and how well it performs. The eight summary variables covering air quality, comfort, design, perceived health, lighting, needs, noise and temperature were all higher or better than the UK 2011 BUS Housing benchmark. Comparisons against the dataset showed that five of the summary variables for Forgebank were either the highest or second highest performers when compared against other studies. This is an exceptional achievement.

General challenges to address in the development included: dry air in the houses (81% of responses) which may be due to the MVHR system although it is unclear whether the dryness is perceived positively or negatively, the narrow baths; bedroom shape and size to accommodate furniture; lack of individual internal and external storage space within homes; noise transfer within the homes and between flats; the balcony railings and perforated flooring; lack of area to the front of homes to store wet or muddy items; the poor floor finish; excessive artificial lighting provision, poor light switch location and wiring; and complex controls of the heating and ventilation systems.

Interviews

The six households interviewed in January 2013 were extremely satisfied overall with both their house and the community aspects of the Forgebank cohousing development. The residents had been living in their houses for a maximum of five months before the interview; most less. The best aspects of the houses were thought to be; the warmth, the views and being close to community facilities. The worst aspects were felt to be the storage provision followed by the balcony design and the poor flooring that cannot be carpeted over easily. The best aspects of the community were; knowing your neighbours, sharing facilities and the support offered. The worst aspects were thought to be the feeling of exhaustion associated with all the work involved with delivering the project.

Changes in behaviour from having shared facilities were noted. For example, using a shared laundry; eating meals together; cycling more; using the common house for socialising; parents using the children's room; storing bikes and outdoor equipment; using the co-op food store; using the car club on a regular basis; using the guest rooms on an occasional basis; holding community events; sharing outdoor space. Beneficial aspects identified were: socialising, looking after children and sharing resources.

Post Construction Testing

As part of the study, a series of fabric tests was undertaken by Leeds Metropolitan University over the period 8th to 29th January 2013 inclusive on one of the dwellings on the development, a two bedroom 65m^2 end-terraced property (the test dwelling). These are described next.

Pressurisation tests and leakage detection

A number of pressurisation tests were undertaken on the test dwelling; one a few weeks after practical completion, one immediately prior to the coheating test and one immediately after the coheating test (see Table 1). All of these tests were undertaken in accordance with ATTMA Technical Standard L1 (ATTMA, 2010). The tests revealed that the dwelling was very airtight by UK standards (<0.6 $m^3.h^{-1}.m^{-2}$ @ 50Pa) and very few air leakage points were identified (see Figure 4). In addition to these tests, a spot 50Pa pressure equalisation test also revealed that there was no measureable air leakage between the test dwelling and the adjacent mid-terraced dwelling.

The pressurisation tests also revealed that the dwelling did become very slightly leakier following completion of the coheating test. Thermal images revealed that this was likely to be attributable to additional air leakage making its way through the mitred joints on the fixed window lights (see Figure 5).

Date	**Depressurisation only**	**Pressurisation only**	**Mean Air Permeability**	**Comment**
	$m^3.h^{-1}.m^{-2}$ @ 50Pa	**$m^3.h^{-1}.m^{-2}$ @ 50Pa**	**$m^3.h^{-1}.m^{-2}$ @ 50Pa**	
30/10/12	0.55	0.52	0.54	Practical completion test
08/01/13				Pre coheating test
29/01/13				Post coheating test

Table 1 Air permeability results.

Figure 4 Small amounts of leakage at the top and bottom of the opening leaf of the patio door in the master bedroom and at service penetrations under the kitchen sink.

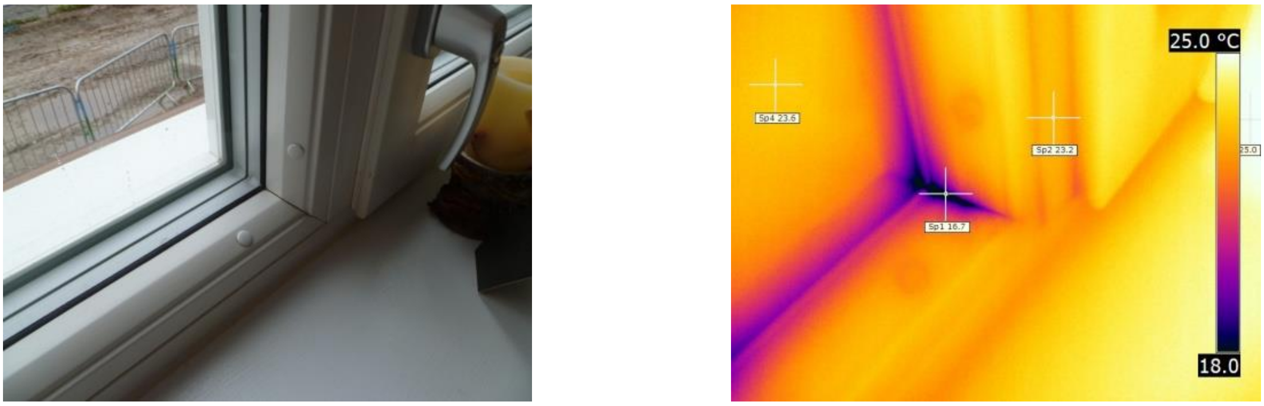


Figure 5 Small amounts of air leakage detected at internal mitred joint on fixed light windows.

Coheating tests

A coheating test was undertaken on the test dwelling with useable data being obtained over the period 16th to the 28th January 2013 inclusive. Unfortunately, it was not possible to control access or heat input to the adjacent mid-terraced dwelling throughout the coheating test period, as this dwelling was occupied. Temperature data from the adjacent dwelling indicated that it was not possible to obtain isothermal conditions on each side of the party wall between the dwellings. Therefore, there will have been some heat transfer from the test dwelling through the party wall to the adjacent dwelling.

For the majority of the test period it was possible to maintain all of the rooms within the test dwelling at the mean elevated temperature of 25°C. However, on a number of occasions, the temperature in the South-facing living area and bedroom rose to over 28°C and almost 30°C, respectively, for a short period of time. These peaks in temperature correlate with periods of high solar insolation. The peaks in temperature measured during the coheating test highlight the difficulties of undertaking coheating tests in very highly insulated and airtight dwellings that have small South-facing rooms in which a large proportion of the external envelope is glazed.

The test results revealed a difference in the heat loss coefficient, with the measured heat loss coefficient being greater than that predicted (see Figure 6) – measured heat loss of 47.1 W/K compared to a predicted heat loss coefficient of 39.6 W/K – a difference of 7.5 W/K. In other words, for every one degree temperature difference between the inside and outside of the dwelling, this is approximately equivalent to one 40W equivalent compact fluorescent lamp.

To put the coheating test result in context, the measured and predicted whole house heat loss for the test dwelling is illustrated in Figures 7, 8 and 9 alongside the results of 22 other new build coheating tests (all of the dwellings were built to Part L1A 2006 or better). The results of these tests have been obtained from a number of projects undertaken by the Centre of the Built Environment at Leeds Metropolitan University over the last decade. On first glance, the discrepancy observed in Figure 8 between the measured and the predicted performance of the test dwelling does appear to be rather large, at just under 20% .However, this is more a consequence of the fact that the dwelling has such a very low predicted heat loss coefficient to start with, so any observed difference between the measured and the predicted performance will appear to be disproportionately large. On closer examination of the results, it is clear from Figures 4 and 6 that the test dwelling represents one of the best performing dwellings in the LeedsMet coheating test sample, with only a very small absolute difference (7.5 W/K) in heat loss coefficient being observed between measured and predicted.

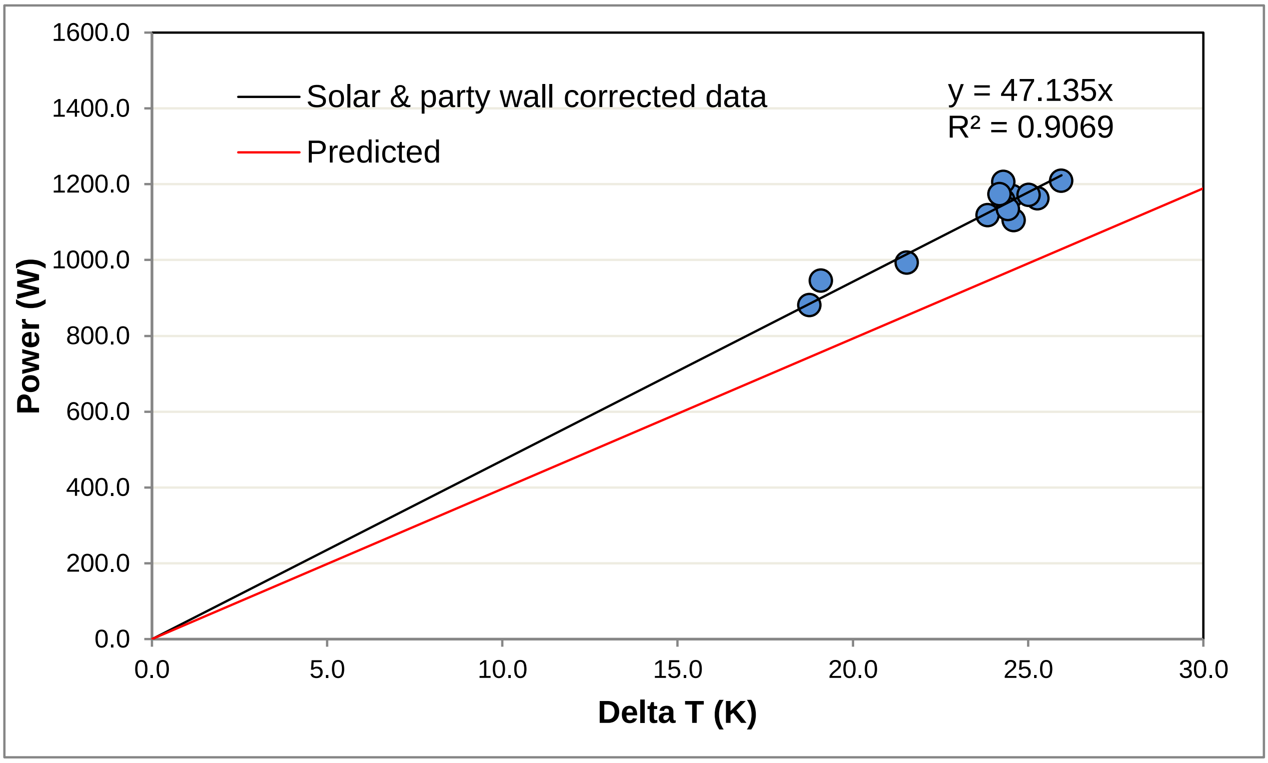


Figure 6 Solar and party wall corrected heat loss data for the test dwelling.

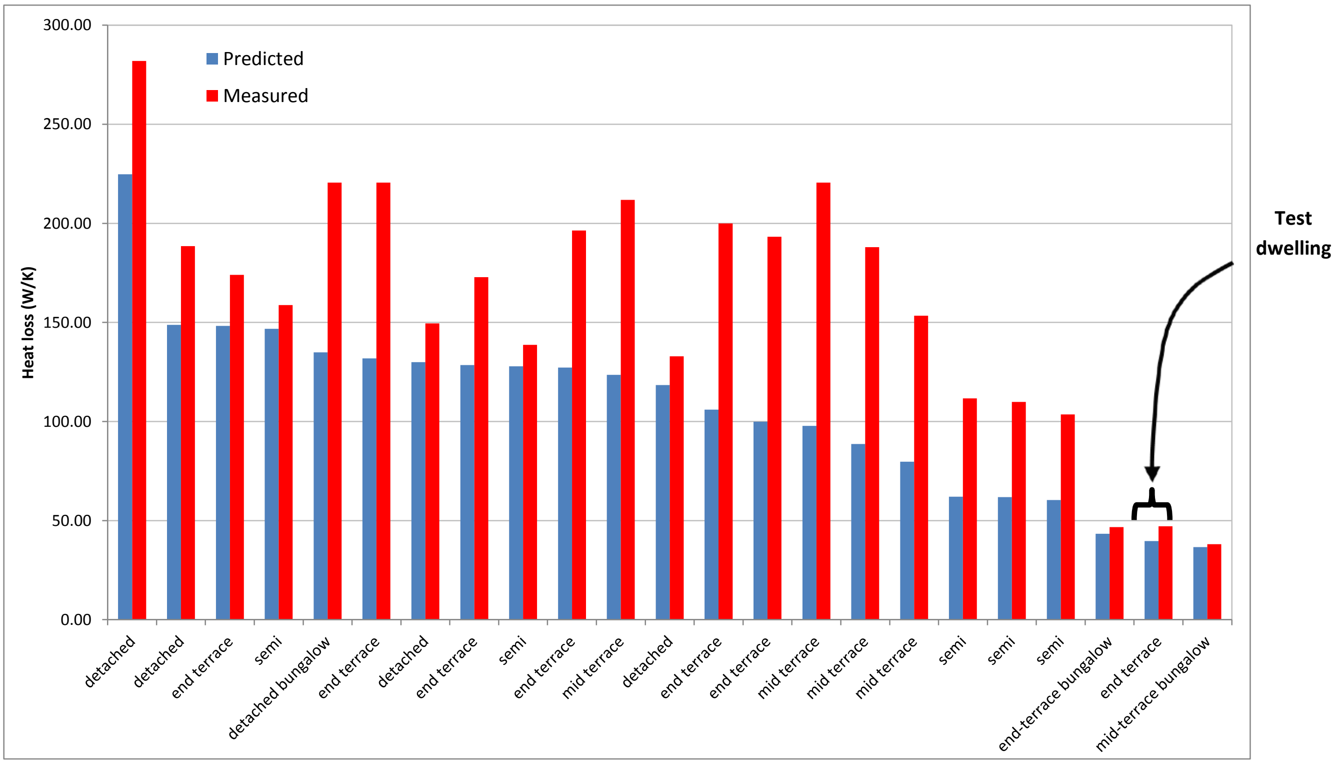


Figure 7 Measured versus predicted heat loss of all of the new build dwellings contained within the LeedsMet coheating database.

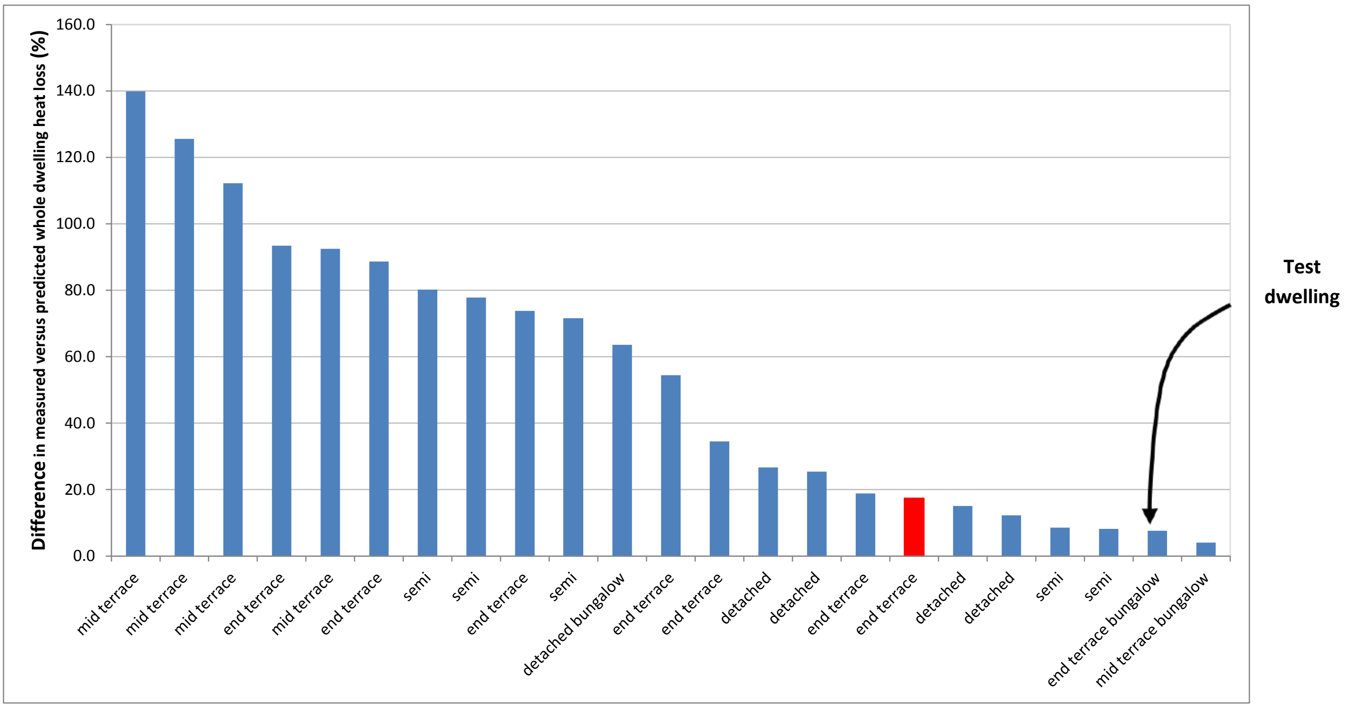


Figure 8 Difference in the measured versus predicted heat loss of all of the new build dwellings contained within the LeedsMet coheating database.

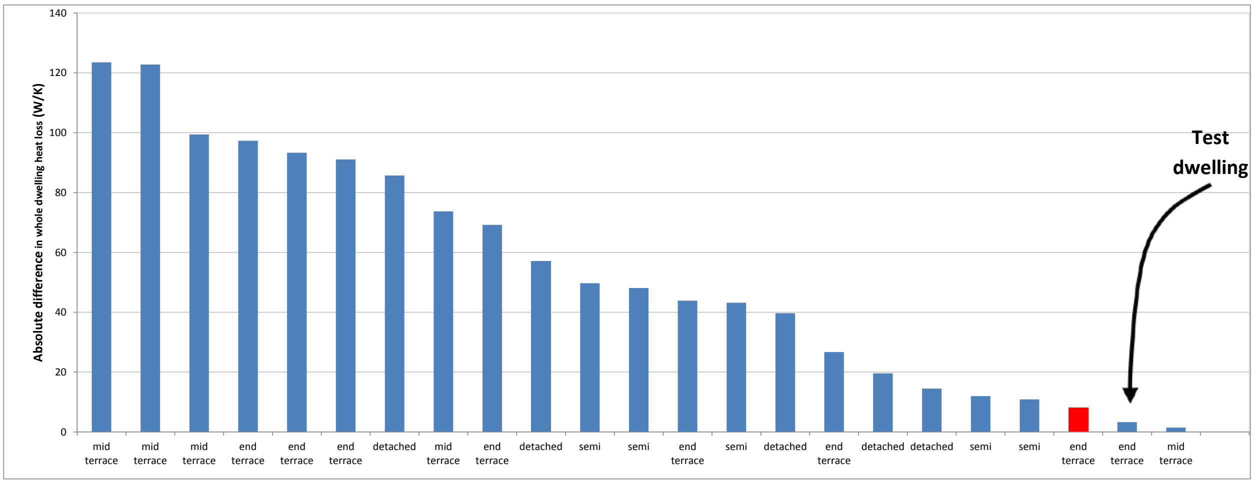


Figure 9 Absolute difference in heat loss between measured and predicted of all of the new build dwellings contained within the LeedsMet coheating database.

Heat flux measurements

During the coheating test, 20 heat flux plates were strategically positioned at various locations on the test dwelling's thermal elements to calculate in-situ effective U-values. It must be noted that heat flux measurements were obtained from a small proportion of the total thermal element surface area during a limited period following building completion. Consequently, the effective U-values presented may not be representative of each thermal element as a whole.

The measurements revealed that overall the floor, ceiling and windows performed very close to their specified design U-values. Measurements on the North facing masonry external wall were severely restricted due to the form, orientation and location of internal fittings within the test dwelling. Data obtained at the location least influenced by thermal bridging, resulted in a calculated mean effective U-value of 0.18 W/m^2K (values ranged from 0.16 W/m^2K to 0.19 W/m^2K), with a standard deviation of 0.004 W/m^2K. This value represents a discrepancy of 0.05 W/m^2K from the specified design value of 0.13W/m^2K. The reasons for the magnitude of this discrepancy could not be established using construction observations and non-destructive testing methods available to the research team. Measurement of heat flux density was not undertaken on the timber in-fill panel section of external wall on the South façade due to the effects of direct solar radiation.

It was also not possible to perform measurements of heat flux density on either side of the party wall, as the adjacent dwelling was occupied. Therefore, the effective U-value of the party wall could not be ascertained with any degree of confidence. However, heat flux density measurements, combined with temperature readings, suggest that the party wall was not acting as a significant heat loss mechanism, performing close to the design value of 0 W/m^2K.

Thermographic survey

A series of Infra-red thermographic surveys were undertaken on the dwellings on different days under different weather conditions. Overall, the surveys revealed that the dwellings performed very well. However, there were a number of areas where unexpected heat loss was identified. The most significant area was at the external wall/eaves junction (both internally and externally) where the insulation had not been installed correctly. Other areas of unexpected heat loss included: two spots above the utility area at intermediate floor height, at lintel edges (particularly on the gable wall), at the MVHR system exhaust and supply grilles(externally) at the soil pipe (externally), at the eaves junction with the North façade, at the external door handles (internally) and around the temporary loft hatch (internally).

We gratefully acknowledge the generous time given by the design team and residents, as well as the funding provided by the Technology Strategy Board as part of its Building Performance Evaluation programme.

Picture 2: Typical View of the completed houses & the Common House Community Terrace

Contributions

Fionn Stevenson holds a Chair in Sustainable Design in the School of Architecture at the University of Sheffield and is a registered architect. Her research and consultancy work focuses on developing innovative methods of building performance evaluation in relation to occupancy feedback in order to improve building design. She is particularly interested in the control interfaces between buildings and people from a holistic perspective which includes resource use in its widest dimension. She currently advises the Technology Strategy Board, Zero Carbon Hub among other government bodies and NGOs.

Kate Fewson is an architect who specialises in building performance through Closed Loop Projects. Her main interest is exploring the performance gap between design intent and buildings in use, particularly from an occupant perspective, to inform designers and clients. Since completing her studies at the Centre for Alternative Technology in 2007, Kate has worked with closely with Adrian Leaman carrying out occupant surveys and exploring the impact of commute based transport emissions.

David Johnston is a Reader within the Centre of the Built Environment (CeBE) at Leeds Metropolitan University. He has managed numerous field trial projects in both new and existing dwellings, involving detailed in-use monitoring of energy consumption and the analysis of occupant behaviour. In recent years, his research has concentrated on investigating the difference between the predicted and the measured performance of buildings, commonly referred to as the 'performance gap'. His work in this area has involved developing methodological approaches to assessing the fabric performance of buildings, exploring the techniques that can be used to quantify the size of the 'performance gap', identifying the reasons why this 'gap' important and examining the various factors that contribute to the 'gap'.

Credits

Client: **Lancaster Cohousing** represented by **Jon Sear** as Client Project Manager

Project Architects: **Andrew Yeats, Vincent Fierkens & Lucy Nelson of Eco Arc Ecological Architecture Practice**

Project Manager and Quantity Surveyor: **David Fotheringham of Turner and Holman**

Structural Civil Engineer: **David Tasker & Gary Willis of Ramboll**

M&E Engineer & Certified Passivhaus designers: **Alan Clark / Nick Grant**

District heating system designer: **Steve Pettit and Rob Clegg of Pettit Singleton Associates**

Passivhaus Certifier: **Peter Warm of WARM Low Energy Building Practice.**

CSH & Life Time Homes Consultant: **Eric Parks**

Main Contractor: **Graham Bath & Charles Whittle of Whittle Construction**.

TSB Building Performance Evaluation: **Prof Fionn Stevenson & Kate Fewston of University of Sheffield.**

TSB Building Performance Evaluation: **Dr David Johnson of Leeds Metropolitan University**

Finished Building Photos (Picture No 1 & No2) **Luke Mills Lancaster Cohousing**

References

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