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Low Energy Case Study - Boundary Close by Eric Parks

Introduction

The Boundary Close development is made up of eight 2 bedroom, with one upstairs bathroom and a ground floor WC bathroom dwellings, arranged in two terraces with four two-and-a-half-storey units in each. One of the unique features of the development is the lack of a central heating system in the design. The panellised timber frame was prepared off-site and is insulated above Passivhaus standards and erected on-site. Testing has confirmed the dwellings to be very airtight and the project was complete with minor over costs compared to a typical social housing budget.

The Boundary Close site is located to the north of York on a site that was formerly rented garages for the City of York Council. The two sets of terraces are aligned along a northeast to southwest axis and positioned within a relatively restricted site to create a dual aspect for four of the dwellings with the remaining four having a single aspect onto a rear garden.

The dwellings are simple in form and modern in appearance with blue stained vertical board on board timber cladding to the ground floors and horizontal ship-lap cladding to the upper floors and clay pantile roofing. The southern elevation of each terrace is articulated with a single change in pitch on the southern elevation that provides shade and cover for a continuous first floor balcony over the main entrances to the dwellings.

The total floor areas of a typical house. Each house is 104m^2 on three levels and comprised of the following accommodation:

Ground floor:	39m^2
Living room:	16m^2
Kitchen:	15.3m^2
Toilet:	2.4m^2
Store:	2.0m^2
Hall:	3.6m^2
First floor:	39m^2
Bedroom 1:	17.0m^2
Bedroom 2:	9.3m^2

Bathroom:	5.1m^2
Landing/store:	7.5m^2
Second Floor:	26.2m^2
Sleeping deck:	21.2m^2
Plant:	5.0m^2

Background

The Boundary Close development was in many ways the culmination of design ideas and approaches that had been developed during two previous low-energy housing projects by Constructive Individuals with York Housing Association. Both previous schemes were super-insulated timber frame designs. The first scheme was a 12 unit self-build development and the second, an 18 unit scheme near St. Niciolas Fields in York that was the subject of a detailed study by Leeds Met that focused on the issues surrounding advanced energy performance standards in housing design. The study involved extensive analysis and testing of the scheme design and construction, most notably airtightness testing of the completed scheme. The in-depth analysis undertaken on the project, combined with lessons learned from the poor airtightness results on the St. Nicolas Fields project, reinforced to York Housing Association the importance of coupling high levels of insulation with excellent levels of airtightness when aiming for exceptional standards of low-energy performance.

In addition to continuing developing the Housing Association's aim to further reduce running costs for tenants, the architect proposed the idea of designing the dwellings without central heating systems, an approach that has been developed most notably in Germany and exemplified by the Passivhaus approach to design. In order to help convince York Housing Association of this approach, the architect recommended that YHA look at some advanced 'no heat' timber frame projects (by Eden Timber Frame in Cumbria) projects schemes. Additionally, YHA sent their housing manager to a Passivhaus conference in Hannover on a visit organised by the BRE. The combination of the two was successful and YHA were happy to proceed with the idea of designing the scheme without central heating systems.

Although the project was aiming for Passivhaus levels of performance, budget restrictions kept the project from being designed and constructed to the full Passivhaus specification. Once the design was developed, the project was run on a partnering contract (PPC2000), as 'value for money' was one of the core drivers for the project and used a two-stage tendering process. The first stage consisted of contractor interviews and also used questionnaires aimed to quantify performance in areas like sustainable design and health and safety issues. Those contractors, who were successful at getting through the first stage, were then asked, in the second stage, to prepare priced bills of quantities within a fixed budget cost.

A local contractor who had paired with an Irish timber frame manufacturer was chosen and worked with the project team on the re-design of the project as part of a cost savings exercise. The main idea at this phase was to keep the same environmental performance and visual appearance whilst searing for options to save money. Some of the key areas where savings were made included; lower specification windows and doors, use of a contractor proposed combined solar hot water and positive input ventilation system (with solar pre-heat) and, cedar cladding to 'Thermowood' heat-tempered cladding.

The project was built using a panellised I-beam timber frame, which was prepared off-site by Thermal Timber Homes in Galway Ireland, delivered and erected on site. The timber frame manufactuer paired with DuPont to design in and supply a system of airtightness membranes and tape with the pre-fabricated kit.

As the project neared completion, residents were chosen by application process. This non-standard approach was taken because the local authority had concerns about selecting tenants to live in a project with no central heating system, an idea that was viewed with some scepticism by the authority. In August 2008, within a week of completion, the dwellings were occupied. In terms of achievements, the project has attained an Ecohomes score of ‘Excellent’. Many of the project team do feel that the advanced nature of the design would achieve Code Level 4 under the Code for Sustainable Homes accreditation scheme and would also be near Passivhuas levels of performance.

Fabric

Floor

Floating floor construction comprised of 22mm tongue and groove timber boards with all edges glued on two layers of 75mm extruded polystyrene insulation on 100mm concrete slab on ground. U-value of 0.12W/m^{2}K.

Walls

Two types of external cladding: Stained softwood vertical board on board cladding to ground floor; Thermowood horizontal boarding above. The cladding boards fixed to 25 x 50mm battens on OSB sheathing on 300mm engineered timber studs lined internall with OSB and fully filled with mineral wool. An internal service void is provided by fixing plasterboard on 25 x 50 battens. U-value of 0.10W/m^{2}K.

Roof

Double pitched roof finished in plain clay pantiles on a 407mm deep, fully insulated engineered timber joist/rafter OSB clad panel. Pre-fabricated roof panels span from the wallplate to a glu-lam ridge beam. An internal service void has been created using 25 x 50 battens with the ceiling finished with 12mm plasterboard. U-value of 0.08W/m^{2}K.

First and second floors

22mm timber finish

Windows

Double glazed timber windows with low emissivity coating, 16mm argon fill. U-value of 1.70W/m^{2}K.

Rooflights

Fakro rooflights with triple glazed units. Whole unit U-value of 1.70W/m^{2}K.

External doors

Solid and half-glazed timber doors with U-value of 2.0W/m^{2}K.

Air leakage

The air permeability target for these dwellings was $2m^3/m^2hr@50Pa$. The final as-built air permeability figures actually exceeded this target. The average air permeability figure for the end terrace units was 1.58 $2m^3/m^2hr@50Pa$, whilst the mid-terrace units achieved $1.94m^3/m^2hr@50Pa$.

There was a clear understanding by all project team members of what was required to achieve such a low air permeability target. This understanding was reinforced by a combination of measures that helped achieve such low air permeability figures:

- The architect provided drawings with notes regarding the airtightness measures required, including 'pen on section' drawings to show the route of continuous barrier and stressed importance of not relying on mastic as a seal.
- The pairing of the timber frame supplier with DuPont was useful as they provided a dedicated system of airtightness membranes and tapes for use.
- The timber framer was also able to manufacture the roof panels in larger sizes to minimize the number of joints that required sealing in the design.
- A testing regime was established that pressure tested the buildings at the following stages: at completion of the timber frame and air barrier; upon practical completion.

Services

Ventilation

A Nu-aire 'Sunwarm' combined mechanical positive input ventilation unit and solar hot water panels is installed in each dwelling. This unit pre-heats incoming air by drawing it through the solar hot water panels and can reverse this procedure to provide cooling on warm nights. A separate cooker extract hood was provided to the kitchen. An openable rooflight has been provided in the first floor bathroom.

Space heating

Nu-aire & Single 2kW electric panel heater, with a thermostat and timer was installed in the Living Room of each dwelling.

Water heating

Nu-aire solar hot water panels 2 No. L2400 x W1075 x D120mm ea. Feeding cylinder with electric immersion back-up.

Lighting

Lighting included 100% compact fluorescent fittings. For appliances/cooking, tenants were allowed to bring their own (all electric) white goods, with one exception. The housing association stipulated that any tumble dryers had to be condensing models to avoid the need to puncture the internal air barrier for a dryer vent.

Total Energy Consumption

The dwellings at Boundary Close have been occupied since August 2008 but due to a very limited response to a survey request for energy consumption figures, no actual energy consumption data has been obtained. The figures below are estimates from

SAP 2005 calculations for the end and mid terrace units. Cooking and appliance use has been separately estimated, as SAP does not account for either, and the emissions coefficients have been updated to reflect the most recent SAP 2009 figures.

Figure 1. End Terrace Estimated Energy Consumption

Form of energy	*Purpose*	*Usage kWh/m²yr*
Electricity	*Space and water heating*	*42*
Electricity	*Lights, appliances, cooking, ventilation and heating system pumps, fans and controls*	*22*
Total		*64*

Figure 2. End Terrace Estimated CO_2 Emissions

Form of energy	*Emissions Coefficient kg/kWh*	*CO_2 Emissions kg/m²yr*
Electricity (Space & water heating)	*0.61*	*24*
Electricity (Lights, appliances, cooking etc.)	*0.61*	*14*
Total		*38*

Figure 3. Mid Terrace Estimated Energy Consumption

Form of energy	*Purpose*	*Usage kWh/m²yr*
Electricity	*Space and water heating*	*37*
Electricity	*Lights, appliances, cooking, ventilation and heating system pumps, fans and controls*	*22*
Total		*59*

Figure 4. Mid Terrace Estimated CO_2 Emissions

Form of energy	*Emissions Coefficient kg/kWh*	*CO_2 Emissions kg/m²yr*
Electricity (Space & water heating)	*0.61*	*25*
Electricity (Lights, appliances & cooking etc.)	*0.61*	*13*
Total		*38*

Figure 5.
Comparing Energy Consumption with a Building Regulations 2006 Dwelling

Form of energy	*Purpose*	*Building Regs. 2006 Usage kWh/m²yr*	*End Terrace Usage kWh/m²yr*	*Mid Terrace Usage kWh/m²yr*
Electricity/Gas	*Space and water heating*	*146 (Gas)*	*42 (Elect.)*	*37 (Elect.)*
Electricity	*Lights, appliances, cooking, ventilation and heating system pumps, fans and controls*	*37*	*22*	*22*
Total		*183*	*64*	*59*

The total figures of 64 and 59 represent a 65% and 67% improvement on the typical 2006 Building Regulations consumption. Such levels of reduction are not far off those targeted for the AECB/CarbonLite Step Two Energy Performance standard. Passivhaus levels of total energy consumption requires approximately a 20% further decrease in the energy consumption levels to arrive at an 80-85% reduction compared with 2006 Building Regulations.

Figure 6.
Comparison with CO_2 Emissions of a Building Regulations 2006 Dwelling

Form of energy	*Purpose*	*Building Regs. 2006 CO_2 Emissions kg/m²yr*	*End Terrace CO_2 Emissions kg/m²yr*	*Mid terrace CO_2 Emissions kg/m²yr*
Electricity/Gas	*Space and water heating*	*32 (Gas)*	*24 (Elect.)*	*25 (Elect.)*
Electricity	*Lights, appliances, cooking, ventilation and heating system pumps, fans and controls*	*23*	*14*	*13*
Total		*55*	*38*	*38*

The CO_2 emissions figure of 38kg/m^{2}yr, or 3,952kg/yr (3.9 tonnes/yr) in Figure 6 above is a 31% improvement on the typical 2006 Building Regulations CO_2 emissions. However, 38kg/m^{2}yr is still 2.5 times the Passivhaus levels of CO_2 emissions of 15kg/m^{2}yr.

In the absence of any information on actual energy consumption, it is difficult to know how the predicted consumption levels above relate to the actual performance and why they might be larger or smaller or how they could be improved. It is clear that by swapping electricity for a mains gas fired central heating system (with a 91% efficient condensing gas boiler), the likely CO_2 savings would be approximately 1.5 tonnes CO_2/yr for both the end and mid-terrace properties and the CO_2 emissions figures above in Figure 6. would drop from 25 and 24 to around 11kg/m^{2}yr.

One area that would be worth additional investigation is the contribution to space heating made by the NuAire 'Sunwarm' system. Figures provided by NuAire indicate that the energy consumption for the system is similar in performance to a solar hot water system and suggest an average annual energy consumption of 135kWh/yr for the 'Sunwarm' along with a savings of around 2500kWh and 1000 kg CO_2 per annum. It would be interesting to know more about the use (or possible un-intentional mis-use through misunderstanding) of the NuAire 'Sunwarm' system and how this might be contributing to a higher use of the electric panel heater in the properties.

Cost

The total project cost was £834,365 (for 8 units) which is £104,295 per 3–bed dwelling or £1003/per m^2. The quantity surveyor has noted that although the panellised approach can often be an expensive construction method, this project still came in on budget. He also believes that this cost would be even lower on similar projects with 20 units or more.

Although this project was completed on budget, the cost of the houses was 5-10% over typical costs according to the housing association. The project was delivered on budget because of savings made elsewhere. The purchase price of the land, for instance, was low because it was previously owned by the local authority and as the project was part-funded by the Housing Corporation, there was a cap on the selling price. Additionally, an export subsidy was applied to the timber frame, which was manufactured in Ireland, thus making the approach of importing the kit a more attractive option.

Tenant Feedback

A questionnaire for residents, with a feedback form, provided by license from the Usable Buildings Trust, was provided to all residents to obtain their feedback in areas such as health, comfort, lighting, energy use and design. The initial interest in participation was low and only three forms (out of eight properties) have returned complete with all the information barring electricity and water consumption figures. The most notable general comments from the completed forms are below:

- 2 residents felt there was not enough storage, particularly in the kitchen.
- 2 of the 3 responding residents would like more control of heating & cooling and indicated feelings of having little control and one complained about the lack of instructions for ventilation system.
- One resident felt there was too little natural light on the ground floor.
- Although the dwellings were generally found to be quiet internally, 2 out of the 3 residents that responded commented on the noise from the ventilation system.
- 2 of the 3 residents felt the panel heater provided to heat the dwellings was insufficient with 1 of the 2 residents feeling the panel heater was also 'far too expensive' to run.
- Generally, residents feel that their needs are very well met and design is modern and good use of space.

Other comments showed that thermal comfort conditions were satisfactory generally with slightly less comfortable conditions in winter (slightly too cold and more variable temperature). One resident was also influenced by lack of perceptible heating from the 'airconditiong' (NuAire Sunwarm positive ventilation system) resulting in the turning on of the panel heater as well. One final comment to note was that one occupant often has a dry throat upon waking which they feel is due to the 'air conditioning'. These responses highlight two areas that would merit additional investigation:

- The perception of the positive ventilation system (with some solar driven pre-heating) as a source of heat (as opposed to pre-heated, fresh air) at all times of the day.
- The possibility of over ventilation in the dwelling (combined with concurrent use of the electric panel heater), which would lead to difficulty in maintaining warmer temperatures in winter and also higher energy consumption and CO_2 emissions.

Areas for Improvement and Key Successes

Those issues that were identified as difficult or needing improvement included the following:

- Tenant selection process.
- Better explanation of the heating and ventilation system to the tenants (through a formal induction or use of an owner's manual etc).
- The use of the NuAire positive input ventilation system with some pre-heating provided by solar radiation.

There are several key aspects of this project that have been identified by members of the project team as contributing to its success:

- Design was the culmination of previous work between the architect and housing association and as such was well-developed and informed. This is particularly true of the approach to airtightness.
- Everyone committed and interested to a proactive approach / partnering.

- Design team members with experience and skills / contractor and key subcontractors (for the timber framing element) were very willing and capable of learning.
- Airtightness and insulation were achieved – two measures key to the success of th scheme.
- The housing association feels that this project shows that lifestyle changes aren't required which broadens the appeal of such project to a wider tenant base.
- The well developed design, partnered procurement and modern construction method could readily be replicated and scaled up for developments that are two to three times the size of this project, all at a reduced cost.

References

'Pen on section' drawing from 'Low Carbon Housing Learning Zone' report prepared by Leeds Met Univeristy and available at (accessed 17 March 2010):

www.leedsmet.ac.uk/teaching/vsite/low_carbon_housing/airtightness/case_studies/boundary/index.htm