Introduction

Based on the Finish model Scotland’s Housing Expo is a showcase of innovative sustainable housing design. Located on the outskirts of Inverness, 54 new homes have been built creating an exemplar community for future house design and development in Scotland.

Architects for the project were selected through an RIAS competition in 2007. The winning proposal which a+j burridge developed was for a detached house on a prominent site facing the village green. The design was vibrant and innovative with a distinctive identity and was a clear and simple response to a challenging brief.
Competition Brief

As a first of its kind in Scotland, the Highland Housing Fair (later rebranded Scotland’s Housing Expo) aspired to be a catalyst for change in housing design within the Highlands and throughout Scotland. The competition sought house designs which were:

- innovative, creative architectural solutions with a quality of design that would raise the bar for housing design and heighten public expectations
- sustainable: ecohomes was to be used as a benchmark, and the use of emerging technologies, sustainable materials and innovative construction methods was encouraged
- capable of being integrated with other quality designs into an exemplar community.

Following the European model, the Fair was planned to run as a month long event open to the public in August 2009 (which ultimately became 2010), after which the houses would be sold or rented at market value.

The proposed location was an elevated green field site on the outskirts of Inverness in the Milton of Leys area - a well established suburban district southeast of the city centre with views to the North over the Beauly Firth and Black Isle.

Adjacent to housing development land and close to the A9, the location was considered accessible and marketable.

At the time of the competition a draft masterplan for the site had been developed which incorporated a mix and number of units giving a range of house types. It was intended that both the masterplan and the individual houses would reflect the Fair’s desire to promote ecological/sustainable design. The masterplan was to form the framework for the ‘unique’ project.

The competition process required initial registration including the selection of a plot on the masterplan. Architects were also required to enter the competition with a partnering developer who ultimately would purchase the site to develop. a+j burridge entered the competition without a developer partner and selected plot 25 for the following reasons: 1. orientation in terms of passive engineering; 2. position in village (adjacent to green); 3. position in terms of visitor arrival for the expo event.
Masterplan design requirements

The brief for the competition was the Urban Design Framework (UDF) document which included plot codes and sustainability design criteria. The UDF stated the key objectives of the Fair Architecture were to achieve the following:

- Showcase creative design solutions to encourage an improvement in design standards in public and private sector housing
- Create a sustainable living environment with a focus on the use of local materials and low energy houses
- Encourage technological and construction innovation
- Encourage a step change within sectors of the building industry including component suppliers and self builders
- Capture public imagination and raise expectations in house design
- Promote a distinctive local vernacular
- Promote the creativity and quality of lifestyle in the Highlands to residents and visitors
- Exploit regional development opportunities including trade links and local manufacturing potential
- Encourage innovation in interior and product design
- Enable future Fairs to act as a catalyst in assisting in the regeneration of smaller communities.

At the competition stage the master plan was in draft form and subject to community consultation. Its design was conceived as a response to the local landscape and topography. It prioritised a sense of place, community, resource efficiency and local materials. Plot 25 was located on the principle street, ‘the avenue’, and overlooked the village green. As a corner site, it also faced onto a side street and the southeast court at its rear. Dedicated parking for the house was accessed from the southeast court with visitor spaces on ‘the avenue’. Recycling and refuse points were located in the shared semi-public southeast court.

Plot design codes set out in the UDF indicated general requirements on building form – a set depth of plan (6m), roof height, elevation height and frontage line dictated shallow buildings and long elevations. Plot 25 required the provision for a separate home work unit in the garden.

The relevant ‘zone energy efficiency theme’ for plot 25 was ‘recycling and adaptability’ – architects were required to take account of this in the proposed means of construction and material choice.

The relevant ‘material and colour theme’ for external materials was ‘lightweight and rural’; the minority wall cladding was masonry (including render) and the majority wall cladding was lightweight with an emphasis on the use of timber cladding. The general emphasis on colour was ‘within the landscape – greens, heather, bracken etc.’
Sustainability

The environmental brief (of 2007) included the following summary and requirements:
• The UK target for CO₂ emission reductions from domestic properties is a reduction of 20% of 1990 levels by 2010
• The Scottish Renewable targets are 18% by 2010 and 40% by 2020
• The Stern Report recommends a reduction of 60% by 2050

The technical component of the competition submission required: 1. a statement of sustainable design (SSD) and 2. a BRE ecohomes statement. A community heating system throughout the site (no need therefore for gas supply) was to be provided but was omitted later.

The SSD needed to cover the following topics:
1. demonstrating zone based theme
2. contribution to highland economy and communities
3. making best use of site
4. enhance biodiversity
5. low carbon design
6. design to conserve water
7. design in sustainable waste and sewage treatment
8. use of sustainable materials
9. minimise waste in construction and lifetime.

Also the SSD needed to: 1. clarify steps that have been taken to design for sustainability during construction and in long term occupation, maintenance and adaption, and 2. encourage innovative or imaginative strategies for limiting energy consumption or wastage. A BRE Ecobuild excellent rating had to be achieved (this requirement was later dropped).

The following U values were to be complied with (generally a value 20% better than shown by the technical handbooks clause 6.1.2):

<table>
<thead>
<tr>
<th>Element</th>
<th>U Value W/m²K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>less than 0.20</td>
</tr>
<tr>
<td>Floors</td>
<td>less than 0.18</td>
</tr>
<tr>
<td>Roofs</td>
<td>less than 0.13</td>
</tr>
<tr>
<td>Openings</td>
<td>less than 1.5</td>
</tr>
</tbody>
</table>

SAP 2006 Dwelling Emissions Rate (DER) 30kg CO₂/yr.m² or 50% improvement over Target Emissions Rate (TER), whichever was the lower.

Air–tightness

As the U values of a building improve, air infiltration rate becomes the key component of heat loss. To address this issue the following air permeability was to be achieved: 2m³/hr.m²@50pa pressure.
Detail of the cladding design model
Competition Design

Plot 25 was a 3 bedroom detached house with separate granny flat / home work unit at the bottom of the garden. The two storey building was organised with living accommodation at first floor level which, in addition to the environmental benefits, offered panoramic views to the north over Inverness and the Moray Firth and provided a large, flexible living space consistent with the needs of contemporary living. Bedrooms and bathrooms were located on the ground floor.

The house was entered through a two storey conservatory space located at the southwest end. As well as an attractive entrance this space provided a draught lobby and a sun space both for enjoying the sun and taking advantage of solar energy on less clement days.

A canopy covered the bike store and parking spaces and provided a raised deck (sheltered from the prevailing wind, enjoying the morning and evening sun) and a covered drying area. Additional secondary entrances to the house were provided at ground floor level directly adjacent to the car parking and at the upper level from the deck direct to the kitchen area.

The latter provided a connection between living spaces and garden. (Ultimately, the home work unit, upper deck, external stair and secondary entrances were omitted as cost savings).
The highly insulated building used a ground source heat pump to supply the modest heat requirements via domestic radiators. Solar panels on the southeast facing roof provided the energy for hot water requirements. Triple-glazed windows and prefabricated timber construction provided good air tightness. Energy efficient light fittings and whole house ventilation system with heat recovery minimise energy loses.

The dwelling was constructed in proprietary solid timber panel system clad in untreated larch boarding and timber shingles to the roof became timber boarding at the detail stage for technical reasons. Flooring and stair treads are made from recycled timber. Reclaimed masonry was to be used for the hardcore, as aggregate for the footings and in the gabions forming the boundary wall with cellulose insulation made from recycled newspaper or locally sourced lambswool insulation.

The design of the Flower House tackled the issues of sustainability head on but remained delightful and user friendly. The key components of the environmental design were as follows:

**Passive environmental design strategy**

1. First floor living spaces optimise available natural light.
   - More light comes in from roof lights than from windows of the same area, creating a bright pleasant space which saves energy by reducing the number of hours that artificial light is required.
   - First floor living spaces enjoy longer days of natural light, seeing the sun earlier in the morning and it is later in the evening before it is overshadowed.
2. Ground floor bedrooms more comfortable

For best sleep conditions rooms should be cool; the recommended temperature for bedrooms is 18°C whereas it is 21°C for living rooms. As heat rises the most fuel efficient arrangement is to have bedrooms below living spaces.

3. Plan optimises orientation

- Small windows to the north reduce heat losses and large windows to south optimise heat gains.
- The ground floor corridor located to the north acts as a thermal buffer to the bedroom on the south side of the building.
- Ground and first floor storage on the cold north elevation also helps to insulate the building.

Heat Loss

- Lobbied external doors prevent heat escaping every time doors are opened.
- Prefabricated construction means that joints are very accurate giving good air tightness, reducing heat loss through drafts and air leaks.
- Triple glazing
- Highly insulated
- Flexible space – sliding doors close down living space and reduce heat loss in winter and open up in summer, extending living area into sun space.
Active systems

Whole house ventilation system controls the air quality and reclaims energy from the exhaust air.

Solar thermal panels on southeast facing roof provide the energy to heat all the hot water for the kitchen and three shower rooms, topped up by the boiler in the colder months.

Ground source heat pump supplies the modest heat requirements via domestic radiators. An alternative strategy was developed with Buro Happold at the detail design stage.

Sustainable materials

Timber - structure, insulation, cladding

- Timber is a regenerating resource.
- Timber has low embodied energy, confined mainly to transporting it to site.
- Carbon sequestration as trees take carbon from the atmosphere and lock it in, unlike most materials which cause carbon to be released when they are produced.
Prefabrication

- Accurate factory fabrication reduces gaps in construction, leading to better quality of build, fewer gaps and better air tightness.
- Reduces site time.
- Reduces site wastage.
- Reduces cost and embodied energy of transporting excess materials to site.

Water conservation

The house has 3 showers and no baths, consuming less heat and conserving water.

The house is designed with a rainwater harvesting which helps to conserve water and consequently reduce the amount of chemicals used to purify tap water. The system is not presently installed.

Detail Design

Materials

The criteria influencing the choice of materials are wide. The Green Guide to Housing Specification (BRE) identifies these in order of importance:

- Climate change
- Fossil fuel depletion
- Ozone depletion
- Freight transport
- Human toxicity
- Waste disposal
- Water extraction
- Acid deposition
- Ecotoxicity
- Eutrophication
- Summer smog
- Minerals extraction.
Timber performs well against green criteria having a neutral effect against most measures (ozone depletion, toxicity, acid deposition, eutrophication, summer smog and mineral extraction). The BRE rank climate change as the most important environmental issue, giving it a weighting of 36%, more than three times that which it gives to the issue it rates second, fossil depletion. Uniquely, timber has a positive affect in relation to climate change – it acts as a carbon sink storing the equivalent of 0.9 tonnes of CO$_2$ in every cubic metre in contrast to the average building product which adds 1.1 tonnes of CO$_2$ to the atmosphere. Consequently, it was an early decision to use timber extensively, the final building benefiting from timber cladding, wood fibre insulation and solid engineered timber panel external walls, roof an first floor.

30% of energy in the UK is consumed in the home. With improved building insulation levels, heat loss through ventilation has become the significant challenge. Prefabrication offered considerably higher degree of precision than site construction, resulting in higher quality building and a consequential improvement in air-tightness. The fabrication of panels close to the source materials reduces the embedded energy of the product by omitting the transportation of surplus materials to site and the subsequent removal and disposal of the waste. Further, there is more intensive use of the source timber at the factory – there is never the issue of surplus and off-cuts, and timber particles can be used in other engineered products, further reducing the embedded energy.
Cross-laminated timber

Cross-laminated timber (CLT) panels are formed in a similar way to ‘glulam’ by stacking a number of lamellas at right angles to one another and subsequently glued to each other to create panels of up to 18m in length. The finished product is substantially timber - 99.4% timber 0.6% glue – but with a significantly improved structural characteristics.

Currently, CLT panels are not fabricated in Scotland - the panels used in the Flower House were transported from Austria. As a consequence roughly 2.5 tonnes CO$_2$ were emitted in transport. However, since the house comprises of 43 m$^3$ of CLT this represents net stored CO$_2$ of more than 40 tonnes, and by comparison with similar volume of alternative building materials a saving of 83.5 tonnes CO$_2$.

Although Scotland grows an abundance of timber, only a small percentage is high-grade timber used in construction. By forming it into engineered CLT panels, the performance and value of the timber is increased and we were interested in exploring a technology that is particularly appropriate to be produced in Scotland.

As with other prefabricated systems, using CLT panels substantially reduces the site time. Within 36 hours of the panels arriving on site, the shell of the building - external walls, roof and first floor - was erected, as can be seen at www.youtube.com/watch?v=tNLV4MMf pdo.

The speed at which a weather-tight enclosure can be produced using such a system is of particular benefit in the local context where a significant amount of time is lost on site due to inclement weather. The CLT panels were also fair-faced to the interiors, removing the need to apply a board finish and saving additional time.

Insulation

180 mm Pavatherm wood fibre insulation to the outside of the CLT walls gives a U value of 0.18 W/m$^2$ and 300 mm thick to the roof achieves 0.13 W/m$^2$. The outer layer of insulation is PavathermPlus, which is impregnated with latex and a tongued and grooved edge detail, forming a breathable waterproofing layer.

Timber Cladding

The house was designed to be clad with horizontal timber boarding on both the walls and roof. An extensive selection process was carried out with close consultation from Edinburgh Napier University Centre for Timber Engineering and timber suppliers to specify the timber which satisfied the various and conflicting demands of durability, sustainability and price.
At the competition stage sweet chestnut was specified as it was domestically grown and durable without the need for biocide preservatives. However, this was eliminated by the client on cost grounds. The timber used as roof cladding is subject to a much higher moisture load than when used on a vertical wall. Fungal decay risk increases as a function of moisture load and so the timber needs to be relatively resistant to decay. In addition, the roof timber cladding is subject to extremes of wetting and drying, increasing the risk of splitting and warp. The selected timber species had to have a low susceptibility to both. As a consequence, British and European standards require that timber used as roof cladding needs to be at least durability class 2 or be preservative treated to a use class 4 specification. The timber also had to have a low movement class and be of a species that is not prone to splitting. In addition to this, we wanted a domestically grown timber from a sustainable source. These imperatives dictated and significantly restricted our subsequent choices of timber cladding.

An additional problem was that to achieve the required fire resistance the roof timbers were to be treated with a fire retardant, and this conflicted with the biocide treatment.

The eventual decision was to use different timber boards for the roof and walls – an untreated domestic timber, Scots larch, for the walls and a durable modified timber, Platowood, for the roof. Although Platowood did not require preservative treating and would readily accept the fire retardant, it had not been tested to show compliance with the relevant standards and as a consequence, a fire engineering report had to be prepared before it was approved by Building Standards.

The Scots larch cladding has open joints permitting some moisture to pass through the timber rainscreen, but also air to circulate freely and allow the construction to dry more readily.

The timber boarding was designed to be turned at 72° to form the large daisy motifs on both the walls and roof – the boards being cut to maintain the chamfered top and bottom edges of the rainscreen profile. Although there was initial resistance to this proposal, once we had produced full details and models of the design it was approved using a half-width board with staggered joints to express the motif. Unfortunately, on site, for reasons of expediency, the flowers were routed into the surface of the boards leaving them with horizontal surfaces and potential water traps.
Design Development

Buro Happold Services engineers carried out various computer based simulations to help understand and tune the building performance. This analysis included the following:

- Glazed area optimisation
- Fabric performance study
- Use of thermal mass
- Daylight studies
- Optimisation of the solar shading
- Thermal comfort studies.

One of the key design decisions at the competition stage was to take full advantage of natural light and solar energy. As in urbanized societies most people spend more than 90% of their time indoors, a good provision of daylight is now considered to be highly desirable in terms of building occupants’ well-being and productivity and poor levels are linked to SAD (Seasonal Affective Disorder) and sick building syndrome (SBS).

In addition, sunlight is a free natural energy source providing both light and heat. This affected our decisions to include the sunspace and locate the living spaces on the first floor, enabling the utilisation of roof lights which have been shown to give around 33% additional useful daylight illuminance (UDI).

Although this decision would prevent the building achieving Passivhaus levels of thermal efficiency, we felt that a reduction in light would be to the detriment of the building users and their experience of living there.

The Buro Happold study helped achieve an optimal balance between good levels of daylight and reduction in the need for artificial light, solar gain without overheating and limiting heat loss, resulting in a net benefit of useful energy to the building.
Overview of Shading Analysis

Three different shading system configurations have been analysed:

Scenario 1: No Shading
Scenario 2: \(d=150\text{mm}; h=150\text{mm}; h/d=1\)
Scenario 3: \(d=150\text{mm}; h=350\text{mm}; h/d=2.3\)
Scenario 4: \(d=150\text{mm}; h=400\text{mm}; h/d=2.7\)

The key aim of the study is to provide summertime shade whilst maximising the potential for passive solar heating during the winter i.e. minimising the increase in heating demand.

N.B. Assuming the ratio of fin-spacing-to-fin-depth (i.e. \(h/d\)) remains similar then different configurations of fin depth and spacing will produce similar performance.

Fuel

The house is designed to have a wood-burning boiler sited on the ground floor with adjacent thermal store and fuel storage. This is linked to underfloor heating on both floors, which is both more comfortable and efficient than radiators, effectively providing heat at low level where it is required rather than at high level. Burning wood from managed sources does not add to carbon in the atmosphere, it does not deplete limited natural resources and reduces our reliance on imported energy. The house currently has a gas boiler.

1 “Working in day lit environments results in higher productivity” Vischer 1989
2 “Learning in day lit environments results in more effective learning” Heschong et al. 1999
3 “A good provision of daylight is now considered to be highly desirable in terms of building occupants’ well-being and productivity”


“…research shows people feel happier, more energetic and have lower sickness rates in the longer, brighter days of summer, whereas moods and health decline during duller days of winter.”

Mayer Hillman, Senior Fellow Emeritus, Policy Studies Institute, University of Westminster, London BMJ 2010; 341:c5964 doi: 10.1136/bmj.c5964 (Published 27 October 2010)

Buro Happold Specialist Consulting, Highland Housing Fair Plot 25, Energy Performance, Daylight and Thermal Comfort Studies (Images by Buro Happold)