TY UNNOS

Affordable building system from locally grown softwoods: Ty Unnos (house in a night)

Prototypes: system and componentry, Smithsonian Pavilion, Environmental classroom & Longhouse

by
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in collaboration with the following industrial partners:
Coed Cymru
Kenton Jones
Cowley Timberwork
Burroughs

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Gwent Wildlife Trust

'The low carbon option is the only viable future to pursue. An innovative system which offers a practical solution to this challenge as well as offering jobs and training in the provision of affordable homes is not only promising, but the development of the Ty Unnos system, using a readily available resource from home grown Welsh timber, may be one of the big opportunities of our times.

Climate change, fuel poverty, homelessness and unemployment require swift responses to ensure environmental and community resilience. Ty Unnos, now an award-winning system, has been attracting increasing interest because it is able to add value to the timber supply chain, offer job and training opportunities for the timber and construction industries in rural areas and provide energy-efficient, affordable homes using a renewable resource from Wales.

After years in development, I believe Ty Unnos now deserves wider attention to increase both the affordability and range of the product and to demonstrate an exciting response from rural Wales to the key challenge of our times.'

Jane Davidson
Former Assembly Member minister for the Environment Sustainability and Housing
Director, INSPIRE (Institute for Sustainable Practice, Innovation and Resource Effectiveness), University of Wales, Trinity Saint David

'I am delighted to have been involved in the approval process for the innovative project'.
Hugh Mansfield Williams
TRADA

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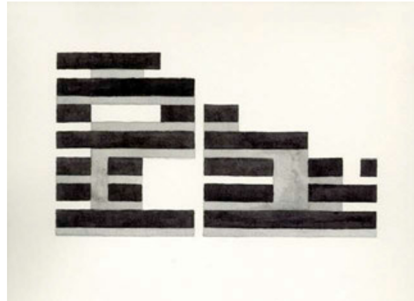

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This design research has been conducted by practitioners and researchers at the Design Research Unit Wales (DRU-w) at the Welsh School of Architecture, Cardiff University. The Design Research Unit Wales is a unique form of practice combining award-winning design, research and teaching. Our aim is to make architecture of simple forms, well crafted, with a strong sense of materiality and inspired by what we see around us; local buildings for local people.

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1 The field project concept drawing
2 Completed Margam Environmental Discovery Centre

Building Simply

Driven by our interest in the vernacular architecture of Wales and a preference for 'rational' over willfully expressive form, the determination to build simply has become an abiding aspiration in our work. DRU-w aim for an architecture made of simple, elemental forms, constructed in a logical, legible and resourceful way from local materials. Our buildings have a sense of authenticity and timelessness, and express an empathy with the context in which they sit. This way of thinking about building contradicts contemporary architectural tendencies where today's global culture has resulted in aesthetic diversity and places value on information, speed, profit and image. To build simply means to design and construct in a direct but refined and artful way, producing buildings of simple form and visual calm often constructed with the appropriate use of a predominant local material. An ethical and economical approach to sensible resource use and a critical approach to site are adopted. Buildings are designed with quiet appropriateness in mind, rather than the louder formal manifestation of other contemporary architecture. Building simply is not concerned with purely visual simplicity; it is concerned with minimisation to give tectonic clarity and not minimalism as an aesthetic style.

Regionalism and environment

Wales has a varied landscape ranging from dramatic mountains and coasts, to market towns and gritty post-industrial sites. Our approach is based on a rigorous investigation of geography, cultural heritage, settlement patterns and urban conditions, to create buildings with a strong sense of place. With respect to this sensitive context and environment our design approach is ethically driven in terms of global responsibility, with passive strategies considered from the outset and renewable technologies considered to enhance the performance of the building envelope. Often projects incorporate didactic demonstrations of sustainability to inform building users about their environment from energy consumption to daylighting and material usage.

Tectonics and material innovation

DRU-w is also concerned with the connection between architectural form, space, culture and the construction process which brings it all together. Tectonics, as the art and poetics of construction, is founded in possibilities for emotional contact between an individual and a building. The ontology of building fabric – the tangible presence which derives from a crafted structure – has the potential to evoke a deep sensory response. Textures, smells, shadows and feelings of a building have real potential to enrich human life. It is this level of construction which is a critical process through which DRU-w interrogates the tectonic as an aesthetic of the built form rather than just a technological category. The act of making, with 1:20 modelling or larger scale prototyping, crafting drawings, developing designs through section and an understanding of the performance of different materials and the construction process suggest and evoke sensory and intellectual engagement, informing our work in collaboration with local industries and suppliers. Such studies embody a curiosity with the expressive potential of materials, technologies, juxtapositions, connections and detail as a formative move in designing structures.

In this research a return to simple, elemental construction is proposed to provide a sense of stability, place and belonging in a fast-changing commercial world alongside the development of an innovative construction system.

Introduction

This research meets a number of needs – how to exploit a technically poor low value resource to make a complete sustainable and low impact building system, whilst enhancing the ecology of the forest and promoting the rural economy and providing architectural exemplars for the contemporary rural dwelling.

Sitka spruce

Sitka spruce was planted, following clear felling over 50 years ago, to produce pit props for the thriving mining industry in Welsh plantations because of its liking for a mild and wet climate and its ability to establish in peaty upland soils. There are now 150,000 hectares of coniferous plantations which produce around a million tonnes of softwood per annum.

In its native range, Sitka spruce grows slowly to a great age. These old growth stands produce a pale coloured timber with exceptional strength to weight ratio, which led to its use in aircraft frames. Welsh spruce grows much faster producing timber of lower density with heavier branching and larger knots. It is processed for a number of markets including fencing, woodfuel, chipboard and pallets but the most important commodity produced is carcassing timber which is machine graded to a maximum strength of C16, the lowest strength class in general use. This is widely sold through builders' merchants for use in general carpentry. Welsh grown C16 spruce is readily available in a range of standard lengths upto 4.8m, a standard thickness of 47mm and widths from 75mm to 250mm. It is seldom used in modern timber frame construction which normally utilises higher grades of imported C24 or TR26 softwood. Although Welsh spruce has poorer structural properties than imported softwoods, it is its tendency to twist during drying that timber frame manufacturers cite as their main reason for not using it.

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1 Example of a typical open timber frame panel manufactured in Wales using imported softwoods
2 Example of an affordable housing scheme at Old Town Dock, Newport by Powell Dobson architects
3 Structurally Insulated Panels (SIPs) manufactured by Kingspan Tek

Affordable housing

A need has been identified in the UK and Wales in particular for affordable rural housing. If there is a distinctive architecture of Wales it is the vernacular dwelling in the landscape. The traditional skills of siting, orientation, form and stringent use of local materials have been lost in favour of a range of generic placeless developments.

This has been paralleled by increasing environmental requirements of construction materials, components and whole building performance. As a result of improved energy performance through the lifetime of a building the carbon footprints and embodied energy of materials is of increasing importance.

At present all of the modern timber frame manufacturers in Wales (and the UK) use imported softwoods because of the greater stability and superior strength of slow grown softwood from cooler and drier climates. If a system was to be adopted by the industry it would need to stabilise the main structural components and eliminate the need for conventional trussed rafters. This would require a radical departure from existing practice.

Timber prefabrication

As a result of the Latham (1994) and Egan (1995) reports and government initiatives such as IMI and MMC (Modern Methods of Construction) there has been an increased drive towards off-site construction in UK housing as a means to improve cost, quality and time. This and the absence of a sophisticated timber frame industry prompted the importation of Scandinavian, German, Austrian and Polish systems.

While the various panel systems in Europe are an efficient and innovative solution they rely on 'high-tech', highly capitalized factories and machinery dedicated to the European crop. There are many variants of this system, but the more advanced structurally insulated panels (SIP) offer the option of creating a watertight shell, often erected in 2-3 days, prior to the installation of services and external claddings.

Currently, the Welsh MMC supply chain is immature compared to that in the rest of the UK. Many of the Welsh MMC manufacturers are receiving larger orders from hotel and fast food retailers outside Wales than from construction and housing companies within Wales. With the correct input, many of the current MMC suppliers have the potential to develop more focused and advanced construction systems.

Research aims and objectives

Initial research and development suggested that this under used and undervalued Sitka spruce could be used more productively within the construction industry. Any innovation with Welsh grown Sitka spruce and other minor softwoods would therefore need to add value, whilst 'fitting in' to current forest management practice, supply chains and minimise the technological requirements, and therefore costs, to fabricate components.

In 2007, a partnership led by Coed Cymru with the Design Research Unit Wales at the Welsh School of Architecture, the School of the Environment and Natural Resources, University of Wales, Bangor and Cowley Timberwork Ltd funded by the Countryside Council for Wales (CCW) and the Wales Forest Business Partnership (WFBP) was established to undertake a feasibility study with a focus on domestic scale architecture. This was further enhanced in 2009 with significant funding from the Technology Strategy Board for a further 2 years of research, development and prototyping, to establish an affordable housing construction system and supplemented by funding from Blaenau Gwent County Borough Council for two buildings on the former steel works at Ebbw Vale – an Environmental Resource Classroom for Gwent Wildlife Trust and a Visitor Centre for the Welsh Future homes Exposition on the same site. This was won by DRUw following an open Design Competition.

Research aim

The primary aim of the study, broadly entitled Ty Unnos - 'House in one night', was to design, fabricate and prototype a solution for the use of homegrown Sitka spruce in an elegant architectural solution for affordable housing determined by the following architectural and technological factors:

- the use of standardised sizes and sections of Sitka spruce and other softwoods available from the local sawmills;
- to use low-tech engineering methods that complimented the available skills and plant to reduce costs and enable quick mobilisation;
- to focus on a domestic scale superstructure system;
- to produce a system that promoted high architectural design solutions and low carbon performance;
- to provide architectural exemplars for the contemporary rural house based on principles of tradition and innovation.

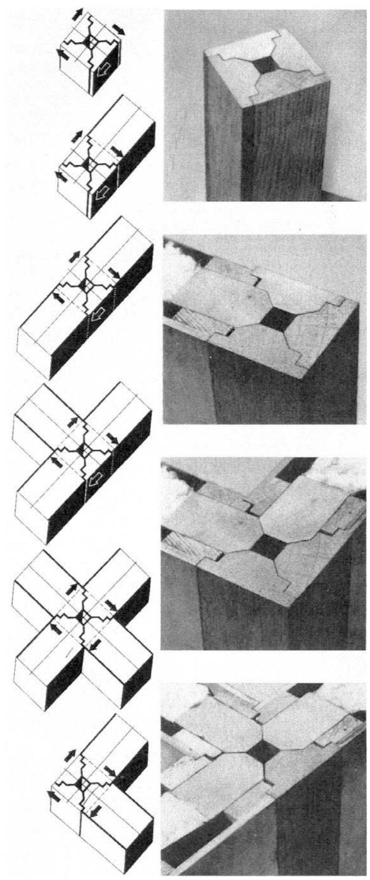
Research method

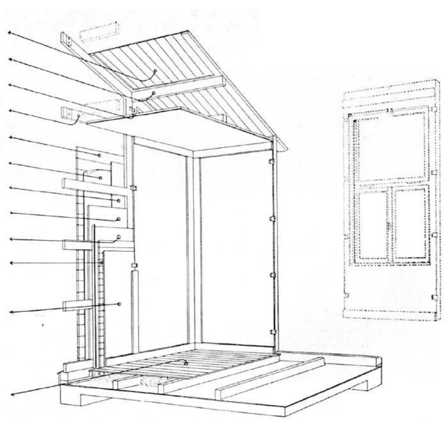
The research was to be conducted as a series of live prototypes primarily through a number of significant projects. The following study can be broken down into the following principle prototype stages and studies that each have their own set of objectives that developed progressively from each prototype:

- The development of the construction system through prototyping components at scale model and 1:1, as well as structural testing and small scale test structures;
- The construction of a temporary pavilion, for the Smithsonian Folklife Festival in Washington DC;
- The design, fabrication and construction of an Environmental Resource Classroom in Ebbw Vale; and
- The design, fabrication and construction of a demonstration, low energy, contemporary longhouse in Ebbw Vale.

Precedent

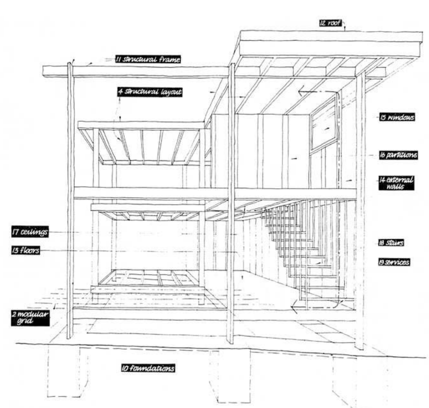
Precedent studies revealed three different architectural approaches that combined similar technical constraints and architectural ambitions whilst complimenting the properties of Sitka spruce and the available skills and technology.





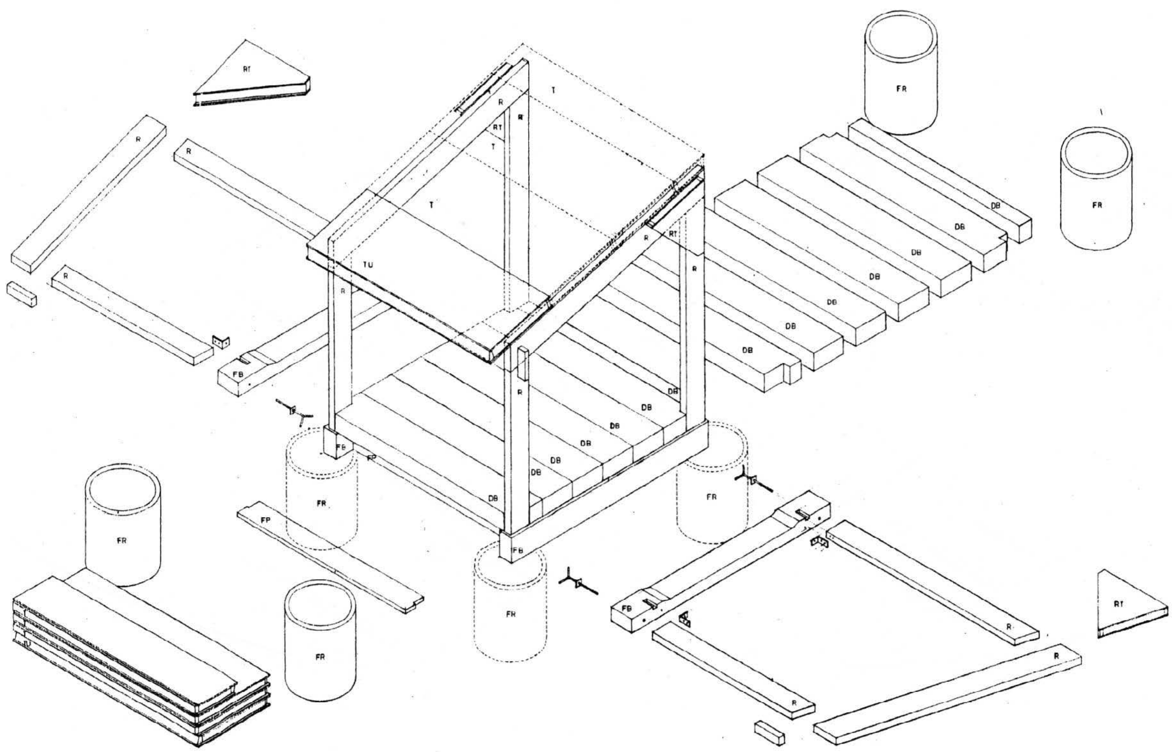
The General Panel System by Konrad Wachsmann and Walter Gropius, used repetitive and standardised elements to provide flexibility in design

image source: Gruning, Michael, Sumi, Christian (ed.), *Building the Wooden House: technique and design* (Basel; Boston: Birkhauser, 1995)



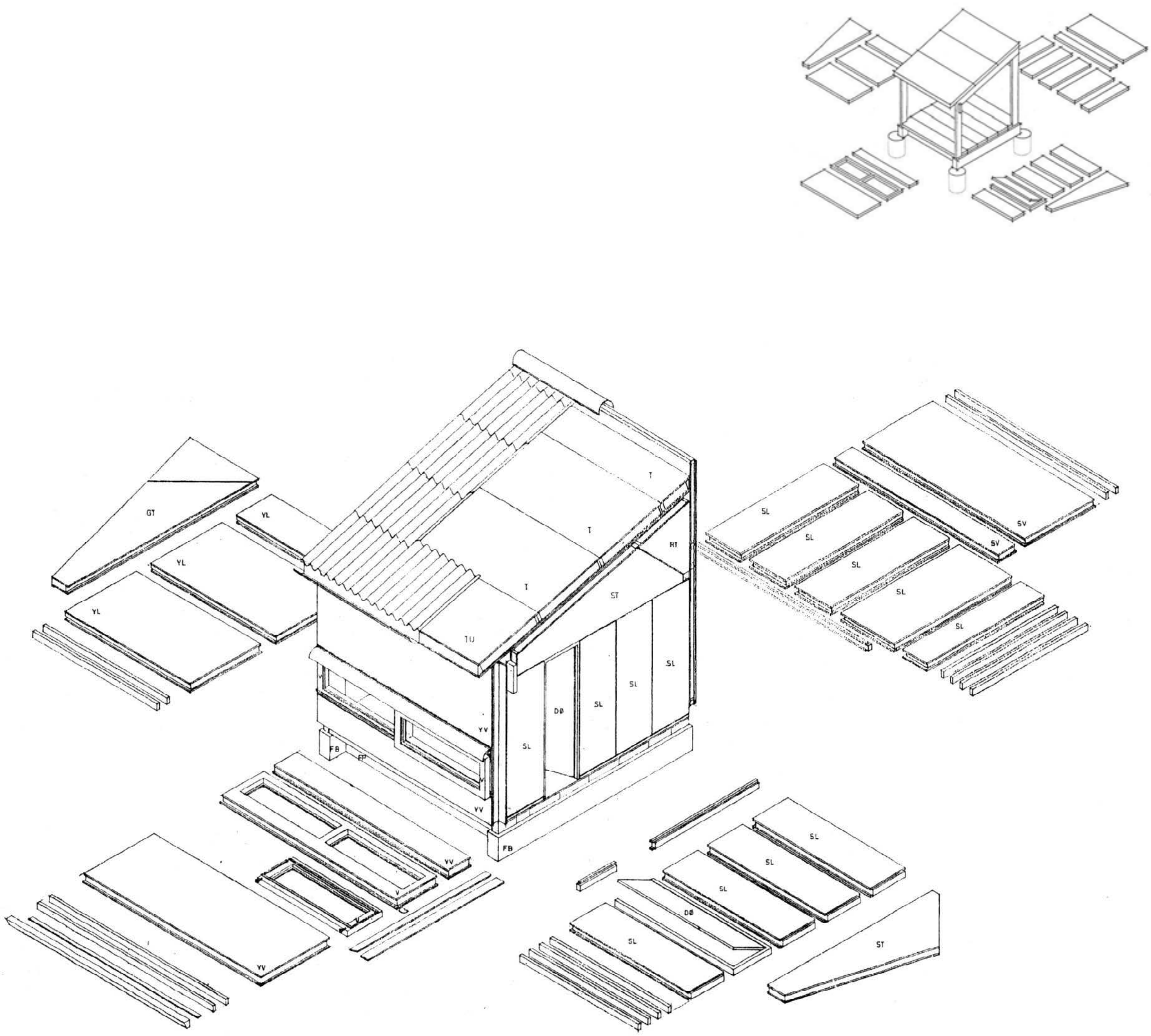
The Segal Method by Walter Segal used sets of standard length and section timber for the simple, unskilled construction of self-build houses

image source: Broome, Jon, 'The Segal Method', *The Architects' Journal*, 5 November 1986, pp.31-68

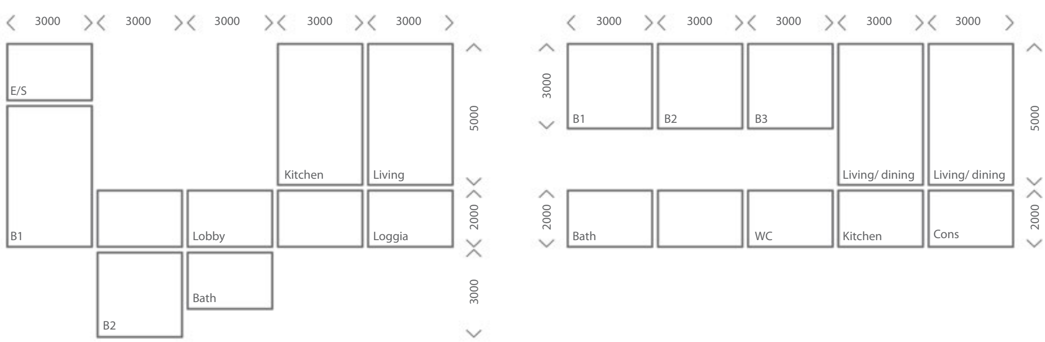


The 'Espansiva' system by Jørn Utzon modularised a complete house into post and beam foundations and portal frames, infill floor, wall and roof panels and finishes.

image source: Utzon, Jorn, *Jorn Utzon Logbook Vol. V : Additive Architecture* (Hellerup: Edition Blondal, 2009), pp.146-148



The ‘Espansiva’ system module layouts



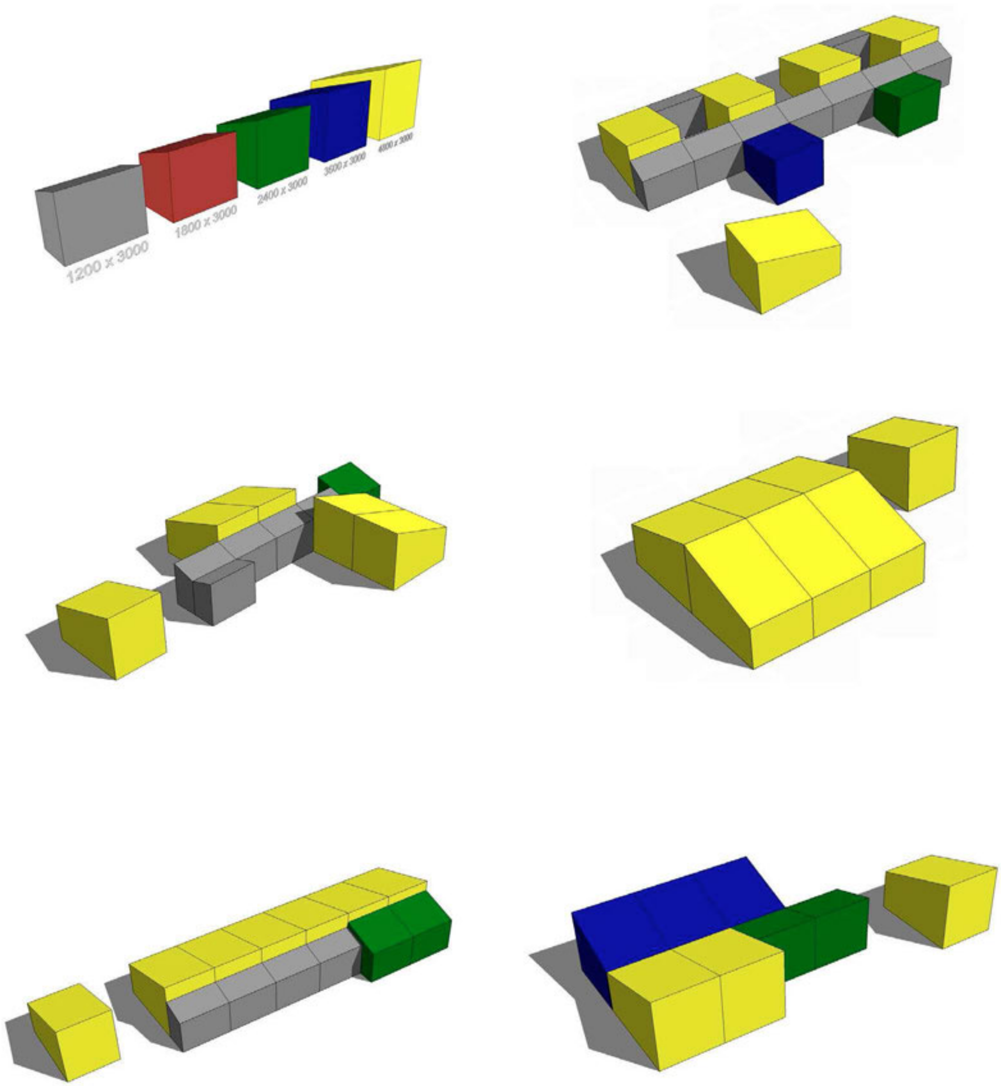
Spatial configuration of rooms based on
module sizes

Feasibility

It was the latter of these that proved most influential in the formation of a number of module proportions similar to the framing of traditional Welsh cruck-framed houses. Each corresponded to both the standard sizes of timber available at local sawmills and the room functions of a house. Initially these were identified as follows:

- 3000 x 1200mm - Lobby, WC
- 3000 x 2400mm - Bathroom, small bedroom, study
- 3000 x 3600mm - Medium bedroom, kitchen, dining room
- 3000 x 4800mm - Living room, large bedroom

Spatial modules were then combined in a variety of ways to form different house types while using the same sections of post and beam with standard roof pitches of flat, 17.5, 25 and 35 degrees. DRUw undertook a design workshop using the 'Espansiva' principles with Mogens Prip-Buus, an associate of Utzon's who had worked on the original system, that provided further details on the design basis of an additive and layered construction system.



Volumetric module arrangements
arranged to form a variety of house types

Concept image of a rural house type, based on early spatial and component studies

PROTOTYPE 1

the system

Introduction

The first prototype stages were to manufacture and then test spatially, visually and structurally the individual components.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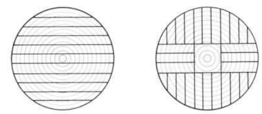
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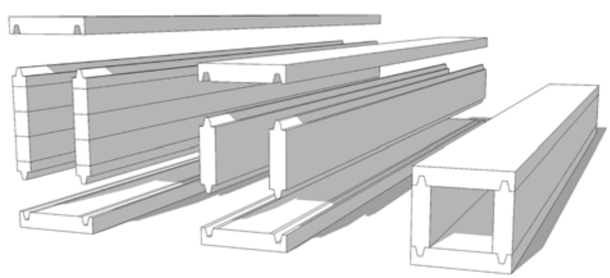
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1 Plain and quarter saw boards that provide the basis of the components
2 Forestry Commission for Wales
3 A typical small Welsh sawmill in Builth Wells, Wales
4 planed Sitka spruce ready for distribution at a sawmill
5 Early Sitka spruce box section types using standard available board sizes

Objectives

Initial thoughts, based on the precedent studies and spatial planning strategies, were to develop:

- repetitive and modular based components;
- a spatially flexible timber post and beam system with infill panels;
- components that were lightweight and simple to construct on-site; and
- provide flexibility in design and future re-use.

The solid section sizes needed to support the required spans and loadings of the largest identified spatial module were too large to be cut from Welsh spruce without including the centre of the tree. Glue lamination of thinner sections to form solid posts and beams was feasible but quickly eliminated due to the cost of equipment and slow process that made it prohibitive for small scale manufacture. Therefore, other engineered profiles, such as I-beams, lattice beams and box beams were considered as they can be produced relatively simply by slotting precut spruce boards together using tightly fitting joints which hold while the glue is curing. This reduced the weight and volume of timber required, simplified the cramping process and increased throughput.

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1 Box beam fabrication process/ sequence at Coed Cymru: raw material, assembly and prototype press
2 First 'portal' frame
3 Early test of end grain bolting for connections between components

Box beam component

The preferred option, influenced by the Espansiva spatial precedent, was to fabricate box section post and beams to generate 'portal' frames. The wall thickness and therefore post size was to be determined more by the required U-values, than by structural loading, and by the qualities of sustainable insulation with 200mm typically giving 0.2W/m2K or better. The box section would use less wood fibre and less labour to fabricate while insulation within the section would reduce the cold bridging effect of solid timber. In the majority of locations a 220mm square box, comprising 2no. 50mm x 225mm (2" x 9"), C16 grade plus 2no. 50mm x 175mm (2" x 7"), was proposed. However, for more highly stressed locations, such as floors and larger spans a 220mm x 280mm box could be used so the whole structural frame could still be built from 50mm x 225mm, ordinary quality spruce.

The initial press prepared to manufacture these prototype box sections demonstrated how simple the manufacturing process is and how easy it would be for other parties to replicate with very low capitalization. The press was fabricated using galvanised steel rectangular hollow sections, softwood, a laminate kitchen worktop and expandable firefighter's water hose. The press and box section profile were designed so that pressure only need be applied for 15minutes to squeeze the box together before removing to finish curing while another section was pressed.

As portal frames, the box section post and beams would provide all the structural rigidity a house requires. This has been achieved through the use of end grain jointing between elements. 6no. M12 or 4no M16 studs are resin bonded into the end grain of a spruce box section. These studs are then passed through an adjoining component and secured with washers and nuts to provide the fixing between all structural elements.

The infill for walls, floor and roof, embrace much the same philosophy. Cassettes or boxes using the same 50mm x 225mm re-sawn to 25mm boards, for all faces, can be made long enough to span in either direction – influenced by standard sized openings for doors and windows.

While this elemental method was a good starting point using 100% homegrown softwood and created a lightweight and strong structure, both modeling and 1:1 prototyping revealed:

- an increased number of individual components rather than repetitive elements;
- more complex details required to reduce the potential for air leakage and thermal bridging;
- while the box section infill components were individually structurally good, as a whole they were over engineered and working independently to one-another.

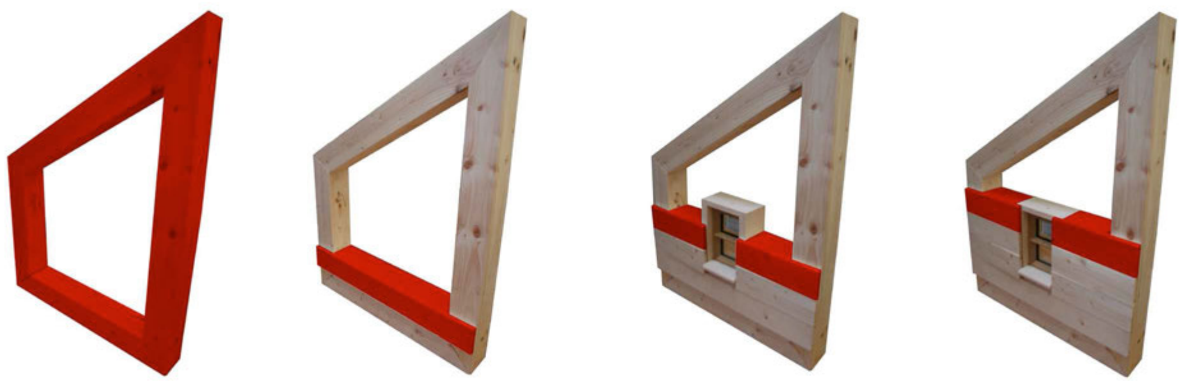
Infill panel component

The system conceived as box section components providing the infill for floor, walls and roof, by simply stacking and spanning between the structural portals, was refined through the development of a larger panel system working on a 600mm component dimension.

Three systems considered included:

- a whole timber system that uses a small section spruce ladder beam with solid spruce boards both internally and externally;
- an OSB system which uses the same small section spruce ladder sandwiched between two layers of Oriented Strand Board; and
- Structurally Insulated Panels (SIPs).

While OSB based components would be simpler to manufacture, it was deemed as less sustainable due to the materials involved and the distance required to transport them. However the use of a whole Sitka spruce infill panel had the advantage of a greater flexibility in panel span, and could provide internal finishes if appropriate. Initial research suggests that all three systems would have an insulation zone of between 200 and 250mm and achieve U-values approaching 0.15W/m2K.



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1 Initial additive infill panel based on the box beam component
2 OSB cassettes with spruce 'ladder' beams for floors, walls and roofs

Box beam load testing at Cowley timberwork.

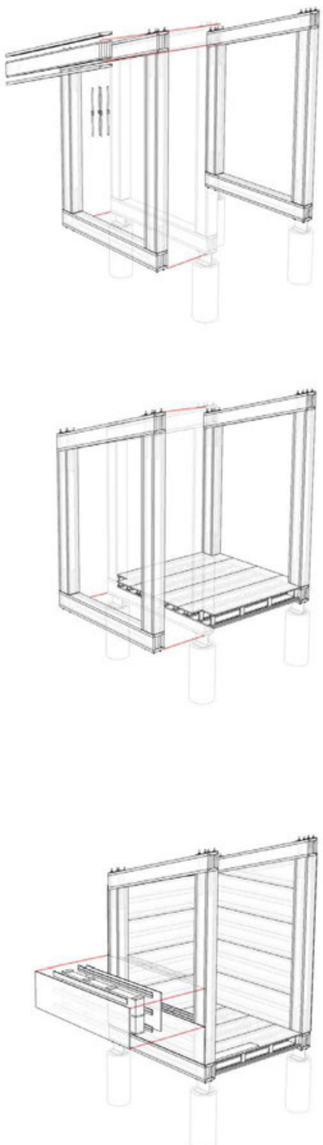
Structural engineering

Structural engineering tests based on the architectural principles for the system were conducted initially by Cowley Timberwork Ltd and followed by Burroughs and Glamorgan University to consider the engineering implications of the system including two options for jointing the box beams, one based on internal steel sleeves the other using laminated hardwood cores.

The detailing of the frame was influenced by the following considerations:

- Recent Post & Beam projects have shown the practical benefits in detailing of square columns slightly exceeding the wall;
- Box sections use less wood fibre and less labour to fabricate while insulation in the void would reduce the cold bridging effect of an equivalent solid timber version;
- 45mm Spruce to C16 grade is readily available up to 220mm wide;
- Pad footings (at column bases only) provide quick and easy foundations suitable for challenging rural sites; and
- Frame spacing is governed by spatial requirements.

Cowley Timberwork undertook structural testing on the Ty Unnos box section in early 2008, firstly on a simple beam and then in the form of a portal frame. Tests on the box section beam were very promising with consistently high loadings being met with great efficiency.



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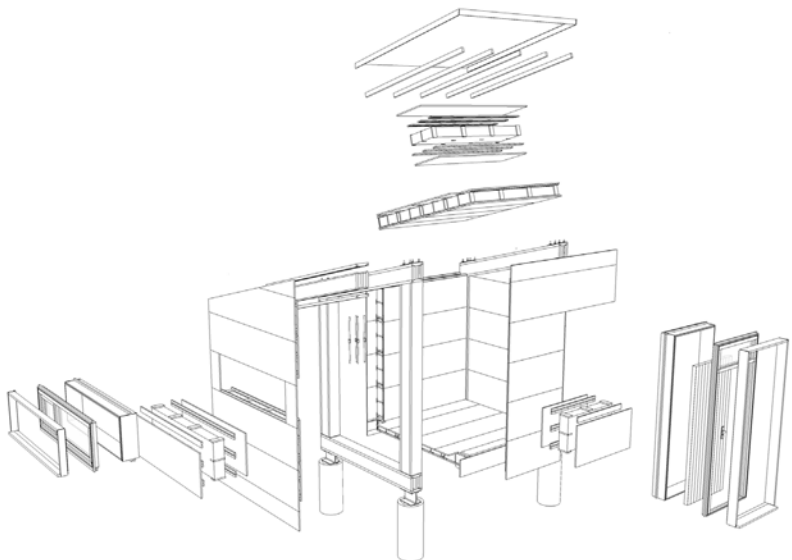

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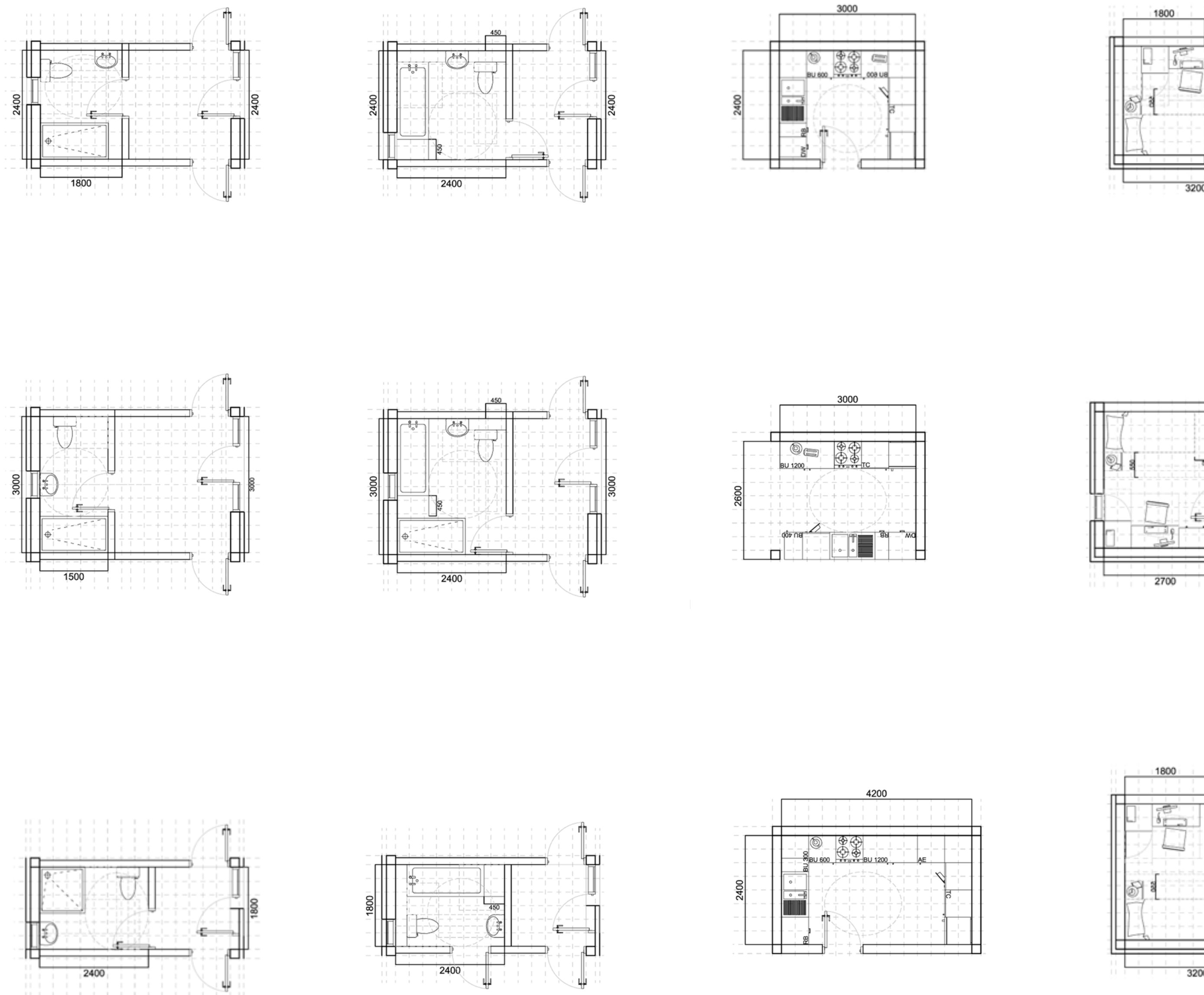
1 Construction sequence of a notional volumetric module
2 Complete assembly of all Sitka spruce components, including standard window and door modules

Outcomes

The first stage of prototyping proved the ability for the box section post and beams with an all spruce infill panel would successfully work at component level. This, in consultation with the wider timber and construction industry, informed the selection of hypothetical room and house layouts based on the following design rules that would inform the design process of subsequent prototypes :

- A dimensional organisation plan based on a 600mm grid, between structure, is employed in plan and elevation to determine the position of; primary structure, internal and external walls, floors and openings.
- A maximum primary structural span of 4.8m.
- A maximum secondary structural span between frames of 3.0m.
- A primary post and beam structure is organised around a 210 x 210mm or 270 x 210mm section size, determining an infill thermal envelope with 210mm thickness for internal and external walls.
- Roof pitches are determined by box section rafters integrated into the primary post and beam frame set at a standard range of flat, 17.5, 25 or 35 degrees that lend themselves to a variety of material finishes.
- A minimum requirement of diaphragm panels will be dependent on building form and site conditions. However a minimum requirement of two 1.2 x 2.4m unbroken panels per floor will be required.



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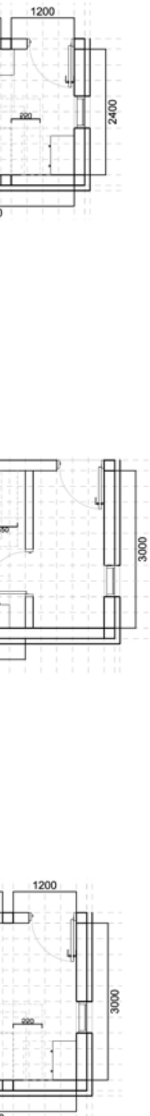
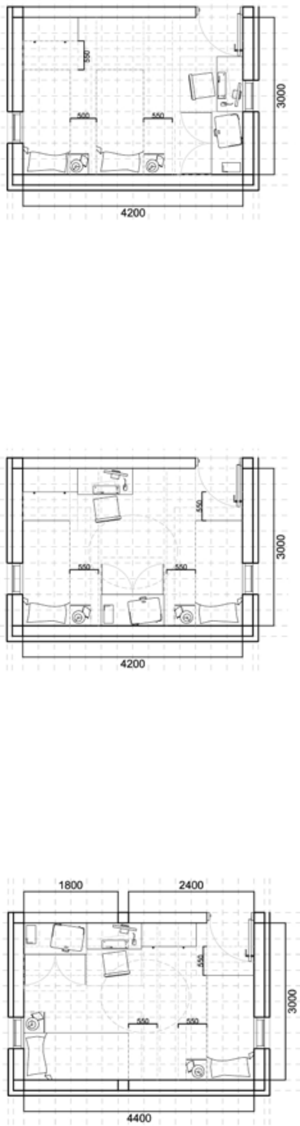
Example room layouts based on the standard spruce sizes and developed components:
1 WC with shower
2 Bathroom
3 Kitchen
4 Single bedroom





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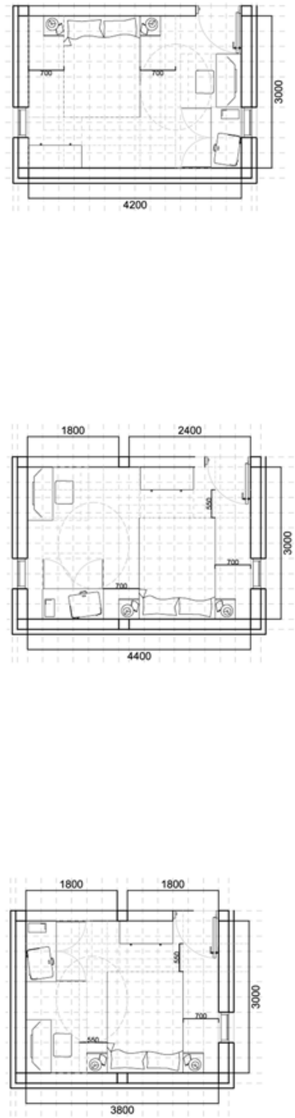

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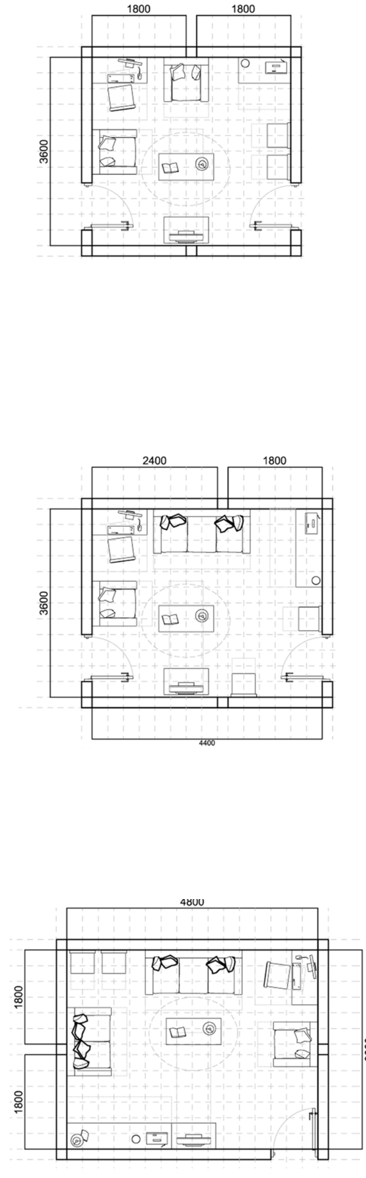

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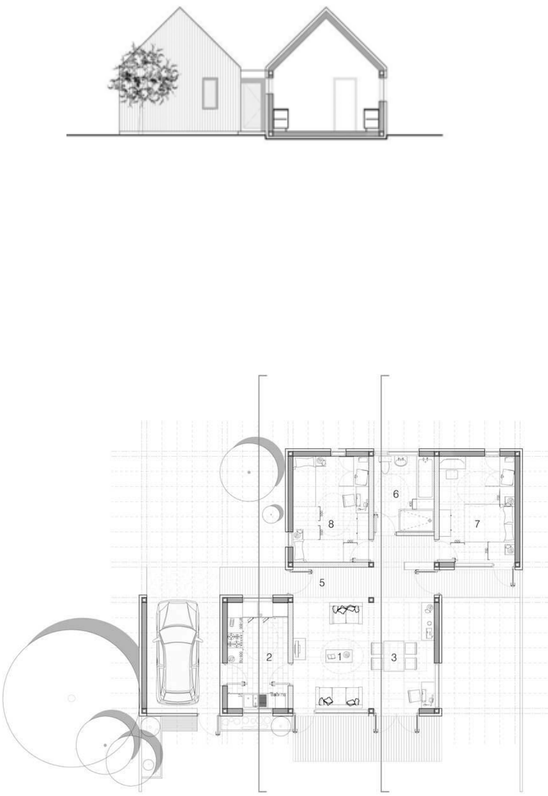
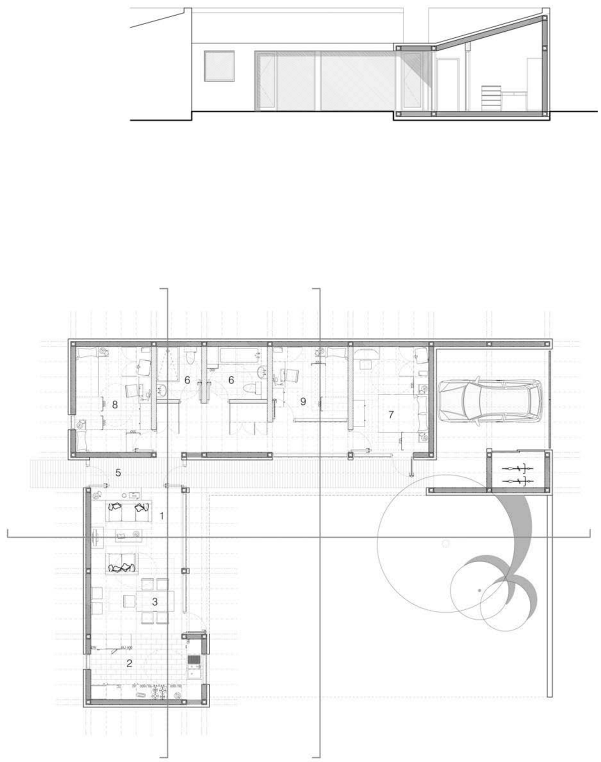
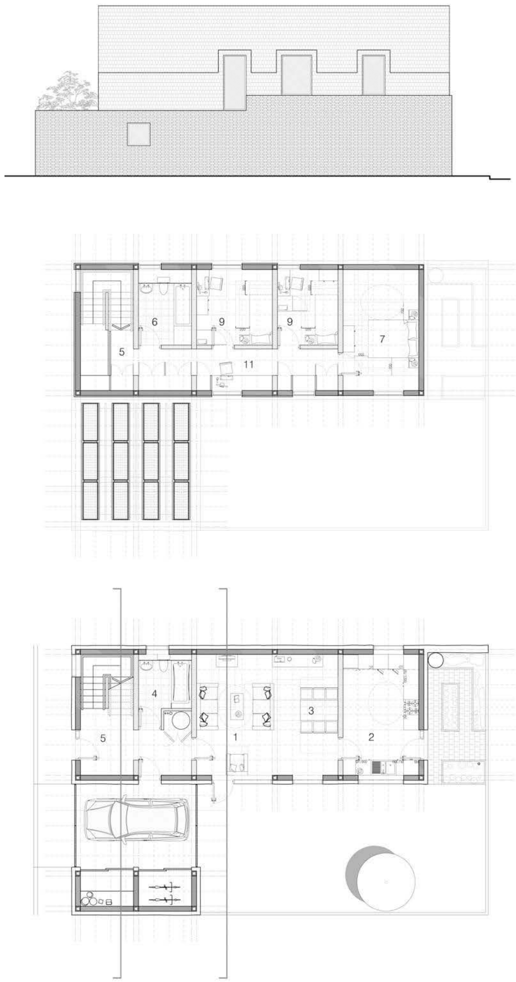
5 Twin bedroom
6 Double bedroom
7 Living room

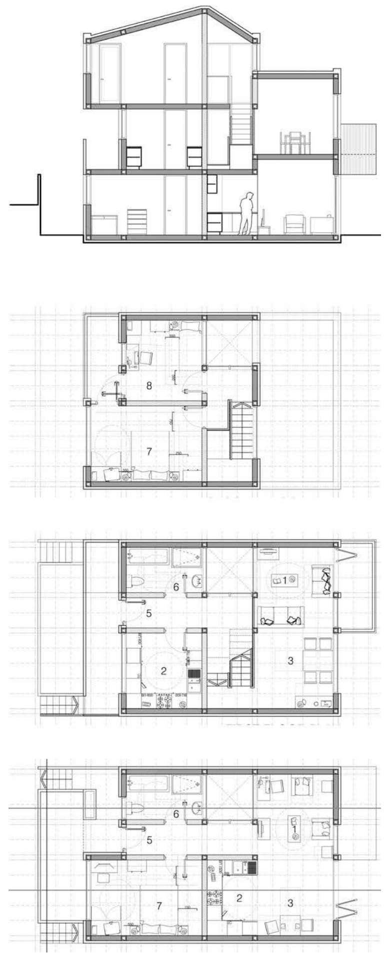




House type 1
A slipped plan separating living and sleeping, public and private areas.

House type 2
Courtyard plan when arranged as a cluster that utilises the linear nature of the frame components.





House type 3
1.5 storey that utilises the longest lengths of readily available spruce to create a floor within the primary frame.

House type 4
3-storey flats, repeating and varying the frame and panel arrangements on each floor within the identified spatial module sizes.

PROTOTYPE 2

Smithsonian Folklife Festival Pavilion

Introduction

DRUw were asked to design an exhibition pavilion for the Welsh Assembly to be part of the Welsh representation at the Smithsonian Folklife Festival in Washington DC in 2009. It was designed to exhibit both Ty Unnos through itself and the history of Welsh forestry and management.

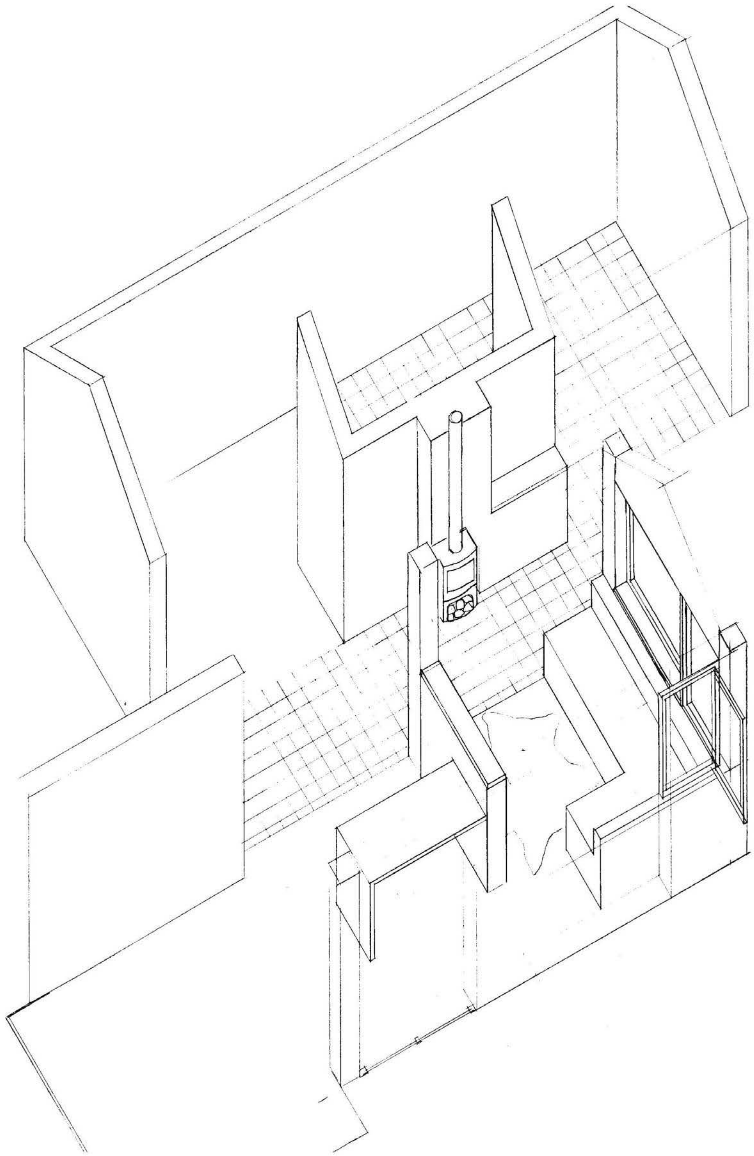
Initial 1:20 construction model of the pavilion

Objectives

This structure was designed specifically around the principles of the early design concepts and house types to test the structural, spatial and material performance of the components in a non-weathertight, un-insulated exhibition pavilion to be sent to Washington DC and built.

The principle aims for this structure were primarily focused on the first use of the Ty Unnos system and as such were to:

- test at 1:1 the use of all box section components in a publicly accessible enclosure;
- use Sitka spruce 'ladder' beams with t&g spruce boards as well as some with OSB/3 for infill wall panels;
- test the use and tolerances of internal hardwood junction sleeves for all portal connections; and
- test the construction sequence for ease of construction, component weights and practicality.



Concept axonometric of the intended pavilion as a representation of the culture of rural Welsh housing

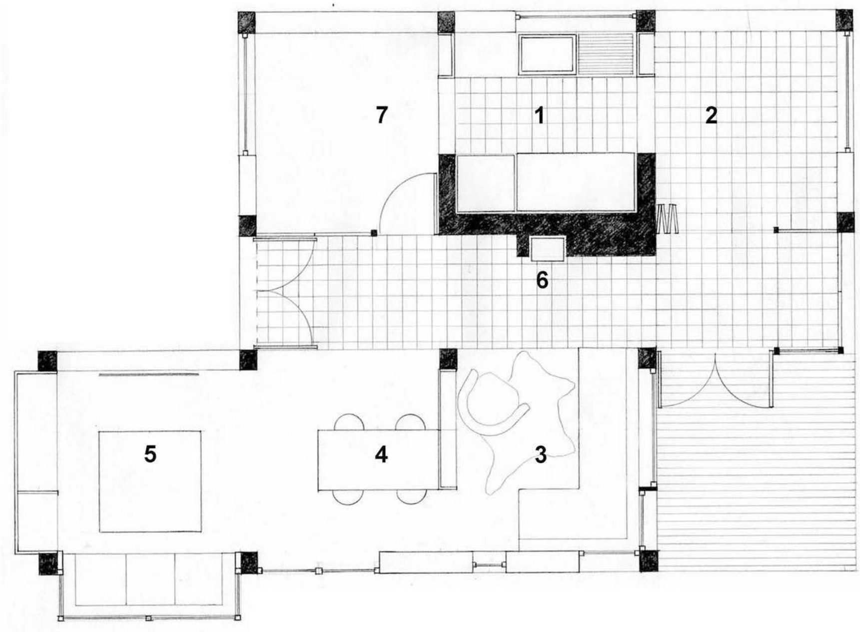
Building Simply

The original proposal, entitled 'learning from the vernacular', was for a two bedroom, single storey, house type inspired by the elemental components of vernacular Welsh rural domestic architecture, such as hearth and zonal separation between spaces. The prefabricated exhibit would be an innovation on the traditional folk culture of Welsh domesticity to generate a contemporary design model encompassing the sustainable concepts of using local resources, recycled materials and low energy design. The vision was to engage with the following traditional design considerations that are all applicable today in contemporary living:

- Rules of siting;
- design with climate;
- laws of building
- the use of local material;
- form and space use;
- custom;
- furniture;
- artefact.

An open plan living, dining and kitchen space are articulated around a central hearth, the 'heart of the home' with a bay window in the living room providing a place to sit in the sunlight. A second bay breaks from the gable end to create a storage wall reminiscent of the crockery filled Welsh dresser. Open roof spaces to the living spaces reducing in scale for the central circulation, connecting front door to rear sun terrace. Two bedrooms and a bathroom form a second wing opening onto the circulation route finished in durable Welsh slate that would provide thermal mass to the heavily glazed rear sun space.

The realised pavilion was a representation of these concepts in a simple three module form with three furniture elements to define hearth, storage and bay seat. The pavilion structure was designed to be predominantly open with a 'peeled back' skin to reveal the different Sitka spruce construction components within. Hit and miss screens and a modular standing seam roof provided protection from the summer sun and showers.



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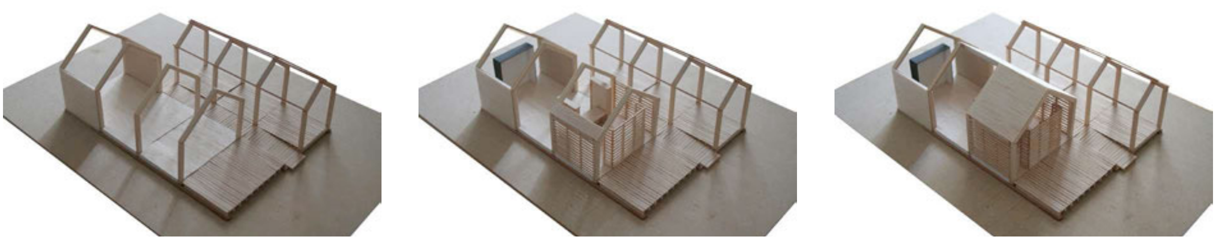

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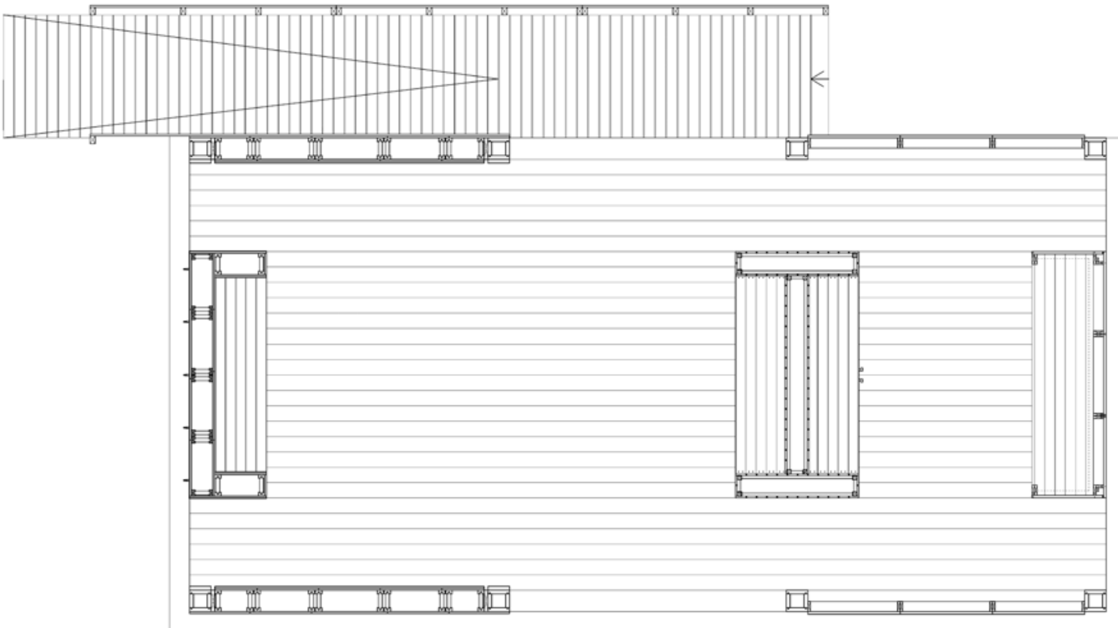
1 Initial plan study for the Smithsonian pavilion based on a 2 bed house-type
2 Construction sequence and components explored through a 1:20 model

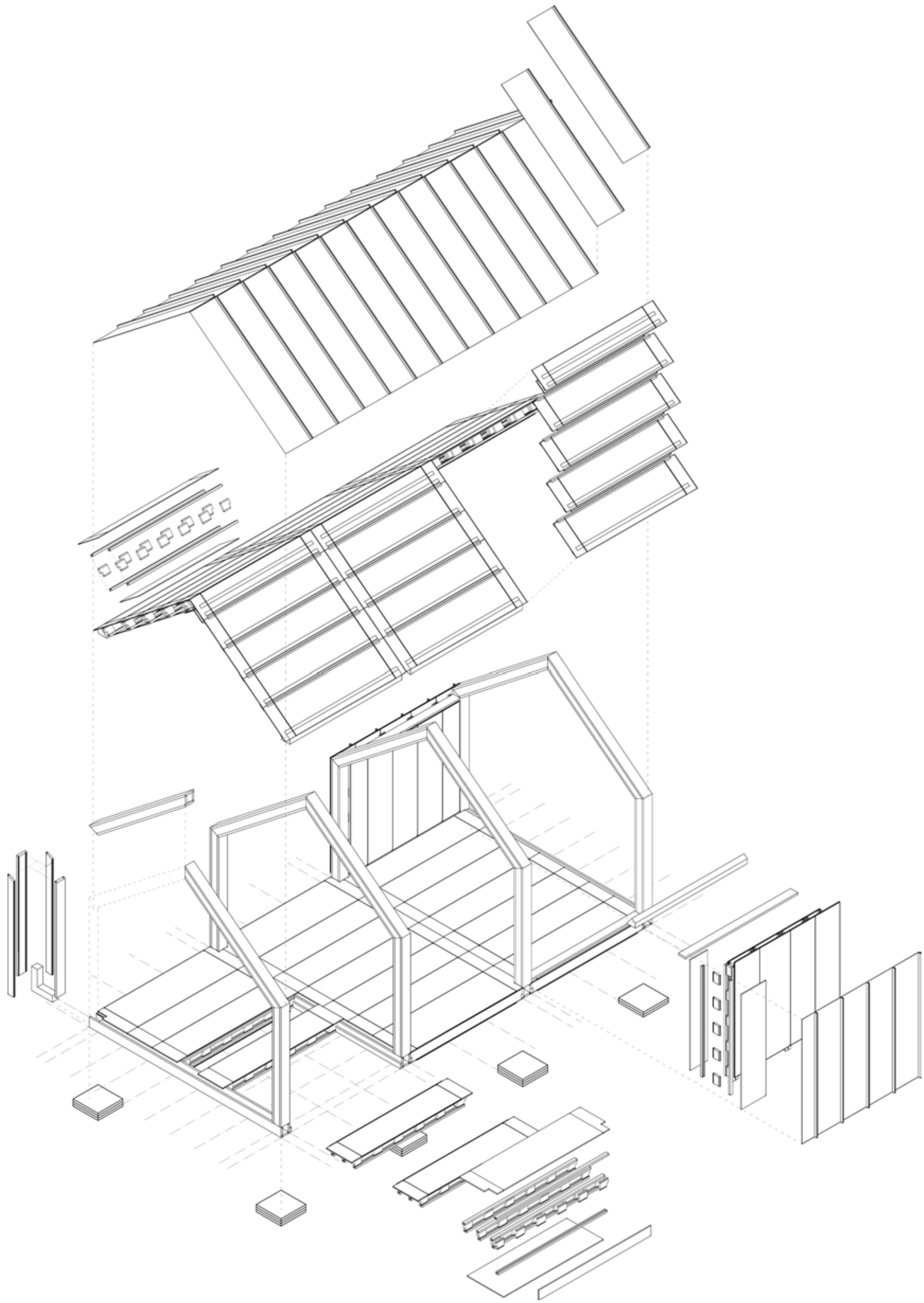


The Smithsonian Pavilion plan as adapted and built to represent the basic elements of the house type and spruce components

Tectonics

The pavilion was based on 3no. 4.2 x 2.7m internal plan sizes with an internal height of 2.4m to eaves, that used a structural panel system for floors, walls and roof based on the Sitka spruce ladder beams in combination with oriented strand board. Internally, Welsh spruce tongue and groove and large section timber are used to finish surfaces and construct a number of space defining furniture units. The pavilion was fabricated in Welshpool, erected in Chirk, before being dismantled, packed into a shipping container and shipped to Washington DC for re-erection by a team in USA guided by two of the original team.

Exploded axonometric of the Smithsonian pavilion components



Beams and columns are jointed using solid section connectors fabricated of 5 laminations: two 45mm cheeks of Sitka spruce, two layers of 10mm steel and a 20mm spruce core. The steelwork was included to increase weight to counter wind loads rather than for structural performance; The frames were arranged from 280x210mm box sections on the flat to check angles, adjusted and fixed prior to being rotated and lifted by forklift to a vertical position;

The entire assembly is fixed by screws; Three type of floor cassette were required for the seven floor panels per bay using the spruce ladder beam arranged at a maximum centre of 300mm. All cassettes are lifted and installed by two people; Five roof cassettes are made up of three different panel types that span between the box-section rafters. These are lifted and installed by hand using scaffold towers. Once in place they self support prior to fixing;

Polyester coated, lightweight, modular steel roof sheets with a pre-folded standing seam from Tata Steel were hand positioned to align with the 600mm building module; Three types of 600mm wide wall cassette were arranged vertically and installed from outside the frame to a sole and top plate by hand; Prefabricated hit and miss spruce cladding panels are hand installed to the north, south and west openings;

Prefabricated panels of spruce t&g boards are applied as a surface finish to the solid walls. A bench seat is installed into both the east and west gable ends, a spruce 'hearth' is fitted in the centre of the plan and a Welsh oak floor is installed.

Completed Smithsonian pavilion on The Mall, Washington DC

Outcomes

The Smithsonian structure provided the first publicly accessible Ty Unnos structure that integrated our design intentions with the realities of a new construction system. While the modular and spatial arrangement demonstrated an ability to achieve versatile and simple designs and the principles of the system were proved under 'real' manufacture, transport and erection conditions a number of technical problems were revealed:

- Successful low-tech erection of frame and panels (no crane needed);
- Ladder beam panels appear to work but further testing required;
- OSB panels proved far more reliable than the t&g covered panels;
- The hardwood insert connector tolerances were not accurate enough - the frame settled over time due to timber movement and allowable tolerance. (future connectors like this would be designed with a smaller angle to compensate for and resist the settlement);
- Structure was easily assembled, dismantled, stored and rebuilt etc;
- The spatial module sizes leant themselves well to the application of other material finishes - such as the Urban Colourcoat roof and wall cladding;
- Level threshold detail and ramp access details highlighted as a potential concern for future projects

PROTOTYPE 3

Environmental Resource Centre

Introduction

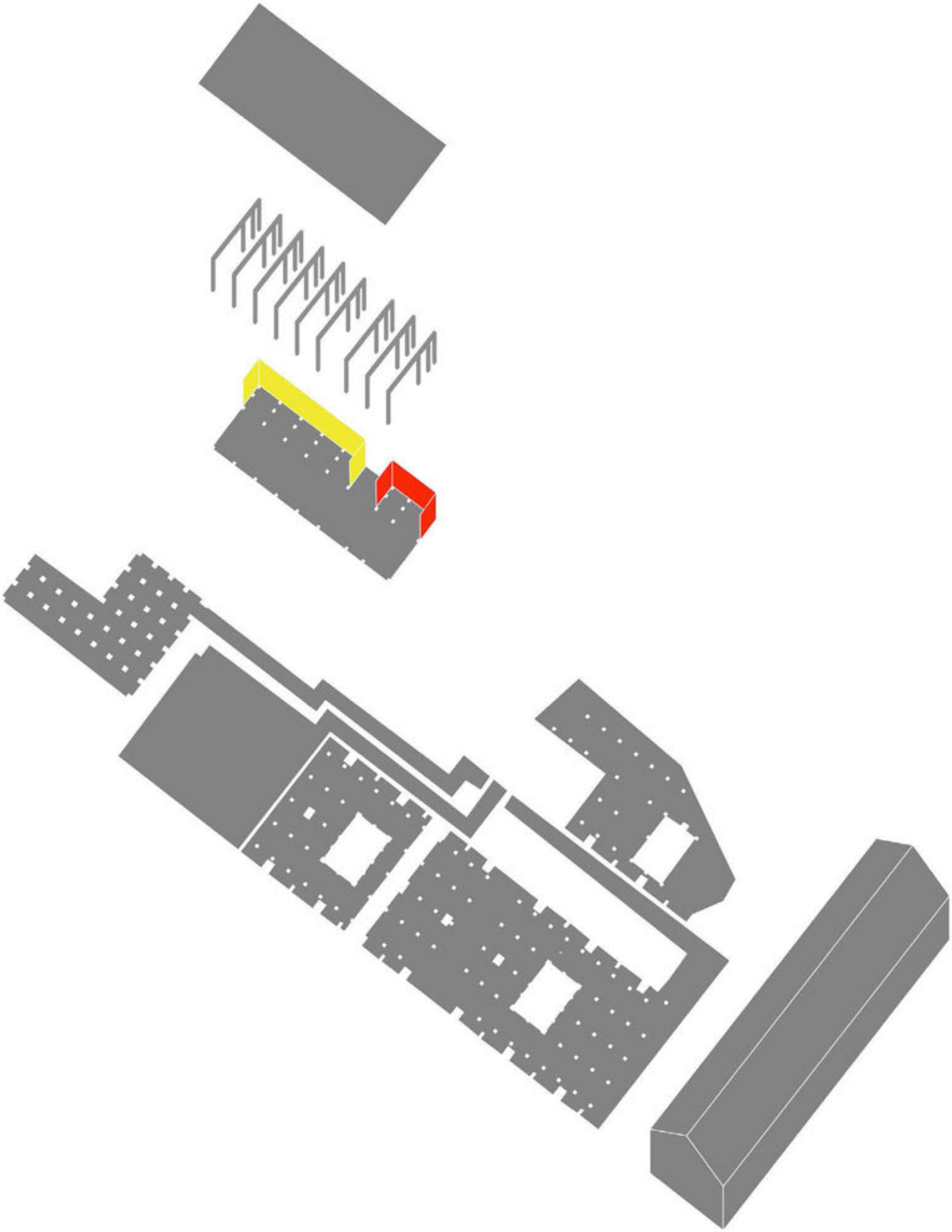
The opportunity to design and build an Environmental Resource Classroom in Ebbw Vale provided the first opportunity to utilise the Ty Unnos components in a fully functioning, weathertight building. The classroom was designed for Blaenau Gwent County Borough Council and Gwent Wildlife Trust and was built between November 2009 and May 2010 as a study into simple, modular construction techniques in a post-industrial landscape.

View of the Environmental Resource Centre looking over the reed beds that have reclaimed the former steelworks filtration ponds

Objectives

While not a domestic building the scale of this single classroom project lent itself to the domestic scale components being developed and therefore provided an appropriate prototype for the system. The aims for the development of the Sitka spruce construction system in the design and fabrication of this prototype were:

- to use the standard sized box section components as a simple frame for ground floor, posts and roof with end grain bolting for all frame connections;
- to use Structurally Insulated Panels (SIPs) as the infill for floor, walls and roof that would provide all the necessary racking resistance for the frame;
- to expose the timber surfaces as the final internal finish;
- to use laminated Welsh oak windows as part of the overall modular system;
- use charred Welsh low value softwood as an external rainscreen to demonstrate a growing integration of the system componentry; and
- To achieve low energy and carbon performance primarily through a ‘fabric first approach’ to the building system.



Concept diagram for the spatial
arrangement and layering of components
within the pumphouse site

Building Simply

The 140sqm Environmental Resource Centre was to be run by Gwent Wildlife Trust, to allow local school children and community explore the heritage and ecology of the former steelworks site. The centre provides: Wildlife courses for people of all ages; specialist courses for school children linked to the foundation and key stages; a focal point and meeting place for community environmental activities and conservation volunteering. Blaenau Gwent County Borough Council's vision for the project was to:

- Create a high quality educational and cultural facility that celebrates the synergy between heritage, built and natural environments;
- Promote sustainable building and demonstrate renewable energy use; and
- Promote the use of the Ty Unnos system in conjunction with other local materials and suppliers.

The classroom is located to respond to the geometry of the former pumphouse and filtration tanks, which have become a haven for wildlife since the closure of the steelworks. The design has been informed by the immediate context of wildlife and materials which informed the following concepts:

- Simplicity - A rational, layered building that expresses construction and environmental strategies.
- Zoning - exploit two key axes:
- Colour and murals - layered facades aim to create a play of colour and depth. The building appears either brightly coloured with wildlife murals or charred black depending on the viewpoint.

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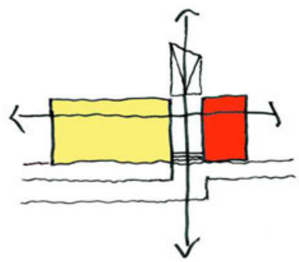

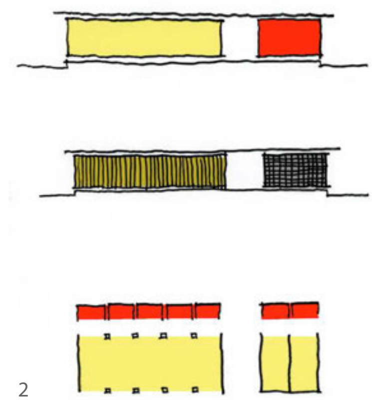

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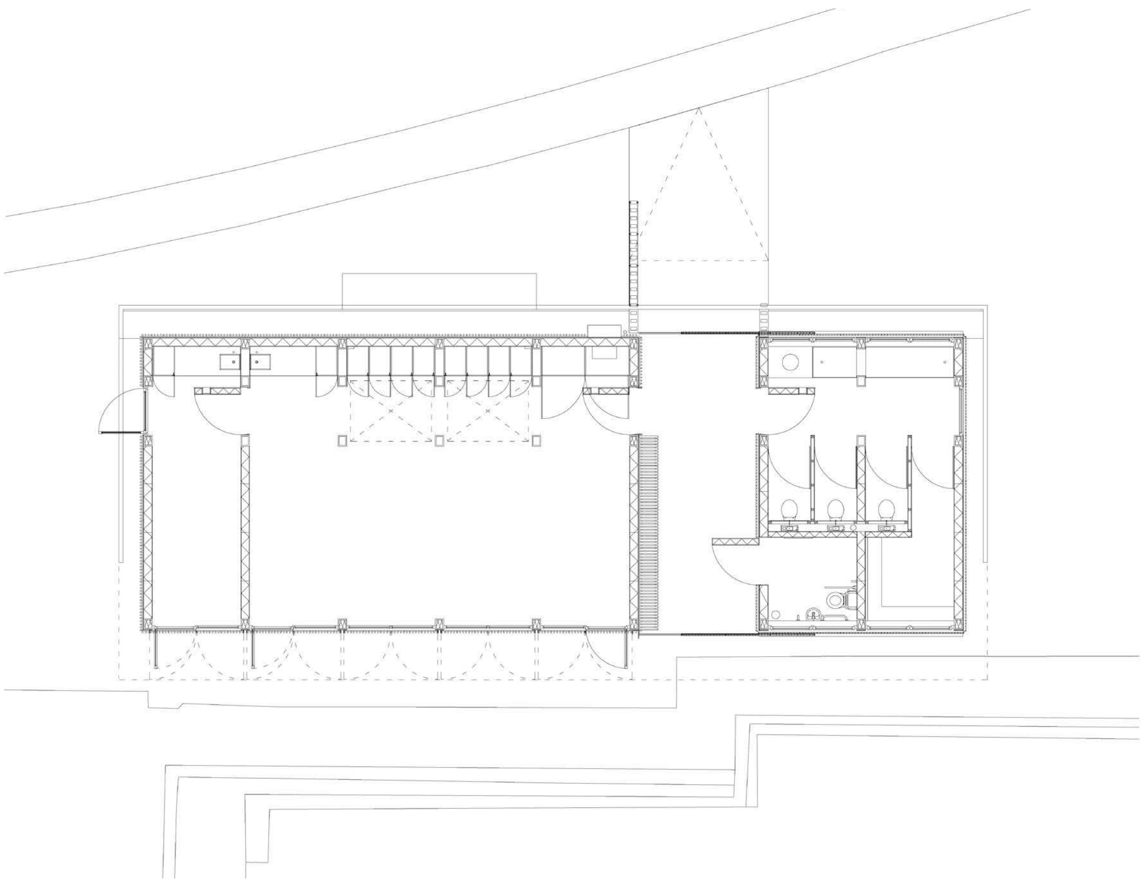
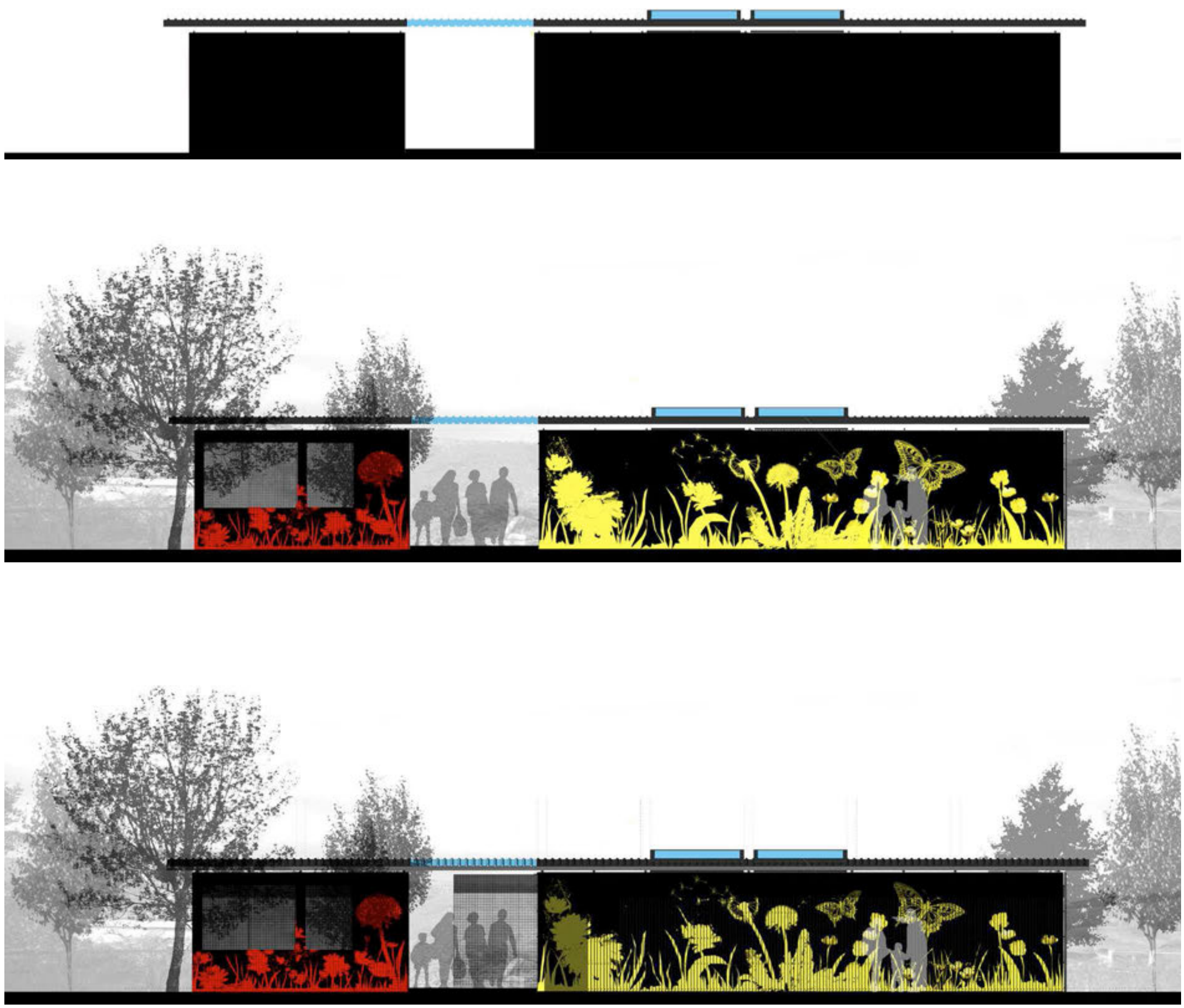
1 Two primary axis for entry and circulation
2 Layering of the facade



The general arrangement plan of the ERC



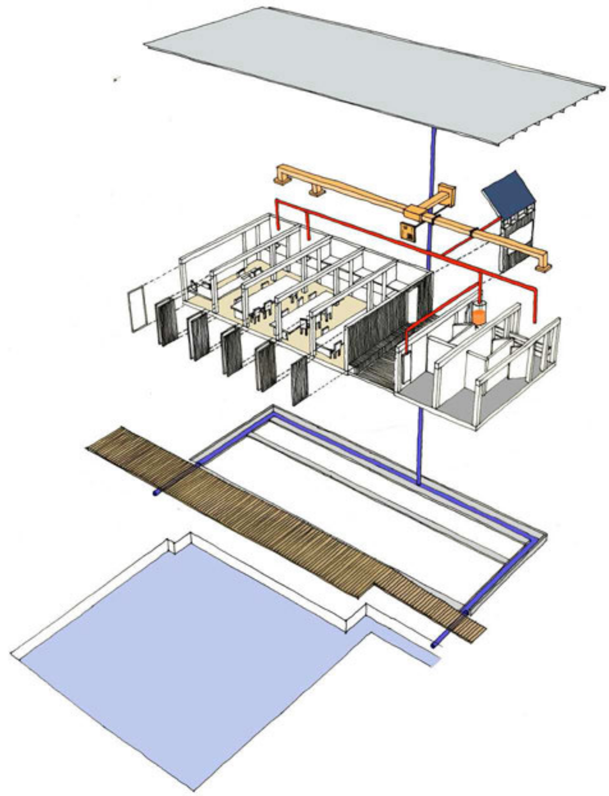
The developed and finished layered elevations: EPDM rubber membrane, mural graphics and mesh/ charred spruce cladding

Regionalism and environment

The ERC was designed to respond to the post Industrial landscape through the form inspired by the existing linear pumphouse building and the use of industrial materials that evoke the essence of the previous use of the site.

The centre is designed to achieve a 60% reduction over Building Regulations. This is achieved through the design of a building envelope which provides high U-values and air tightness in parallel with an intelligent response to site encouraging solar gains during winter and natural daylighting. The environmental performance was to be didactic through the exposure and demonstration of passive and active design measures such as:

- natural ventilation via low level openable panels and rooflights;
- an air source heat pump to provide
- on demand heating in a flexible environment;
- 4sqm solar hot water to meet hot water demands;
- solar control via a 1200mm eaves on the west elevation;
- collection of rainwater and storage in the existing wildlife ponds; and
- exposed M&E linking systems together.



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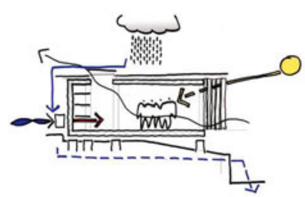

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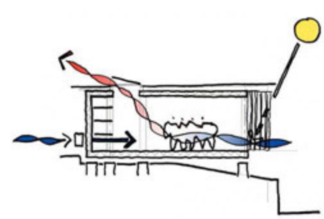

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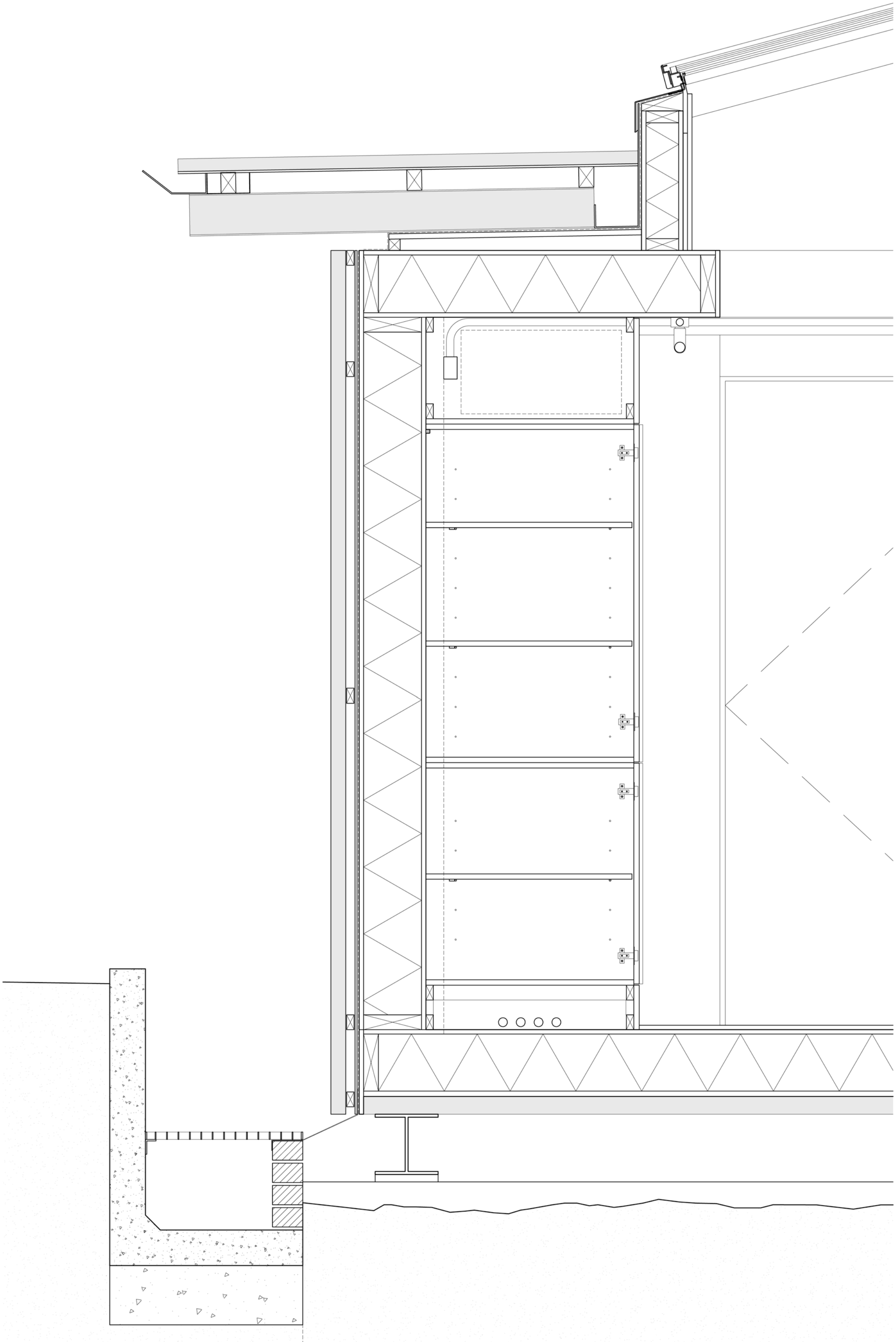
1 Exploded axonometric highlighting the solar hot water and air source heat pump systems
2 Winter environmental performance
3 Summer environmental performance

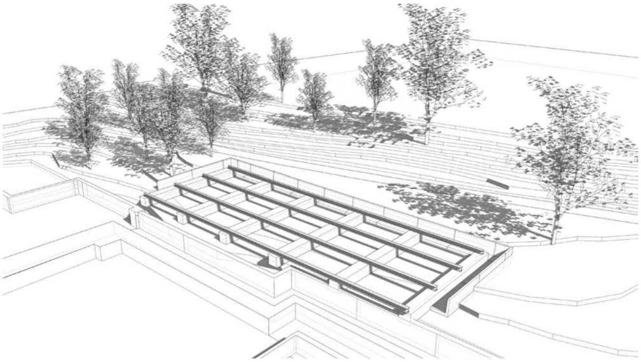
Connection between the ERC and the
wildlife of the post industrial landscape

Tectonics

The ERC uses the standard timber sizes available from local sawmills fabricated into box beams using low tech presses and standard milling machinery. This prototype comprises 9no. 7.2m long portal frames at 2.4m centres with 2.4m x 1.2m birch and spruce plywood Structurally Insulated Panels (SIPs) between for floor, walls, doors and roof. These panels are coated with Envirograf, an intumescent fire retardant, and kept exposed as the internal finish for walls and ceiling. Prefabricated off-site, the box section and SIPs superstructure was assembled in 10 days by a team of 4 carpenters. To improve efficiency and minimise environmental impact a layered, elemental construction approach was adopted. From inside to out: Ty Unnos frame, plywood SIPs with surface mounted services, EPDM rubber membrane, aluminium composite graphic panels, charred softwood or galvanised steel grating and rainscreen roof. Each component was specified to facilitate easy man-handling on-site and a quick erection programme to minimise any damage to the exposed internal timber surfaces.

Construction section through the eastern wall





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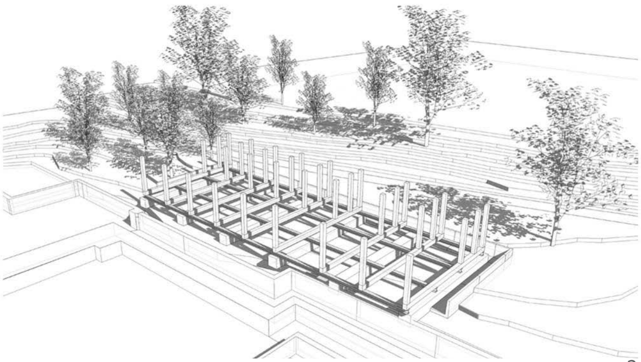

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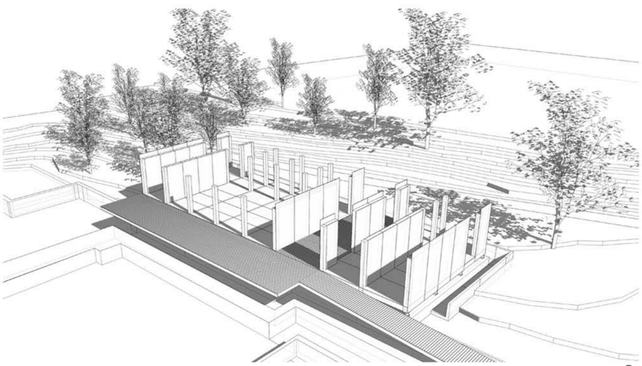

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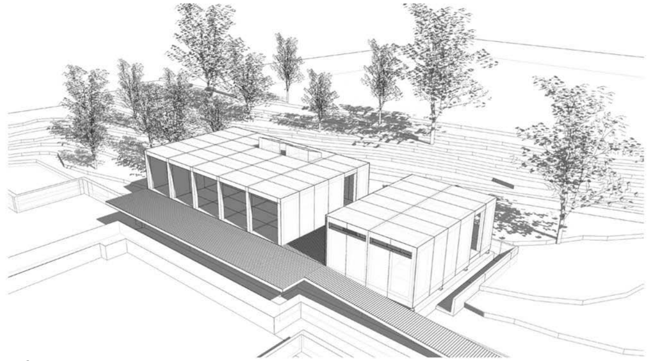
Modelled construction sequence
1 Ground prepared and layered concrete and steel footings
2 Spruce frame erected
3 SIPs floor and wall panels fitted



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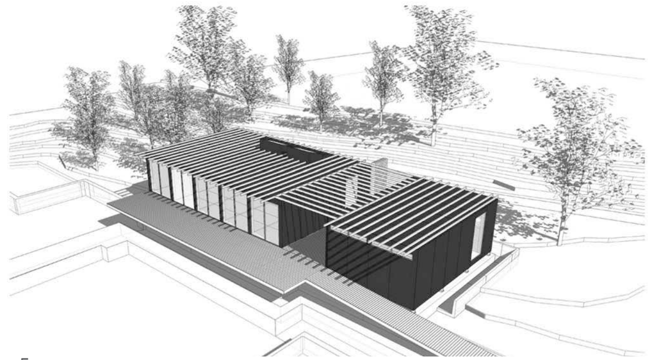

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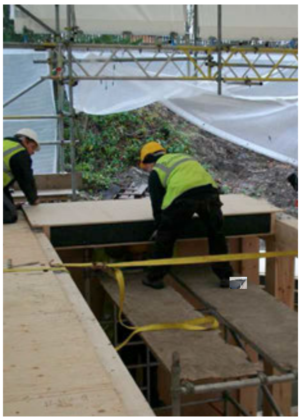
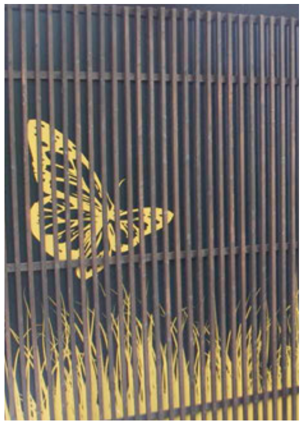
4 Roof SIPs fitted and covered with rubber membrane
5 Windows and steel roof installed
6 Cladding and finishes

Concrete strip foundations were poured with steel I-sections to create a raised floor and support the building; 270x210mm box section posts and beams and SIPs panels were fabricated and pre-coded prior to delivery by Cowley Timberwork to match the construction methodology. The components were delivered in reverse construction sequence and stored in the correct order adjacent to the site to minimise travel distance;

Box section floor beams and posts were moved by forklift, positioned by hand and bolted to the steel foundations and to each other using end grain bolting; 225mm thick SIPs floor and wall panels were hand lifted and inserted externally in to the frame to lap the posts and beams and screwed, providing an internally flush finish between SIPs and frame; 270x210mm box section roof beams are end grain bolted to the posts and used to align the frame;

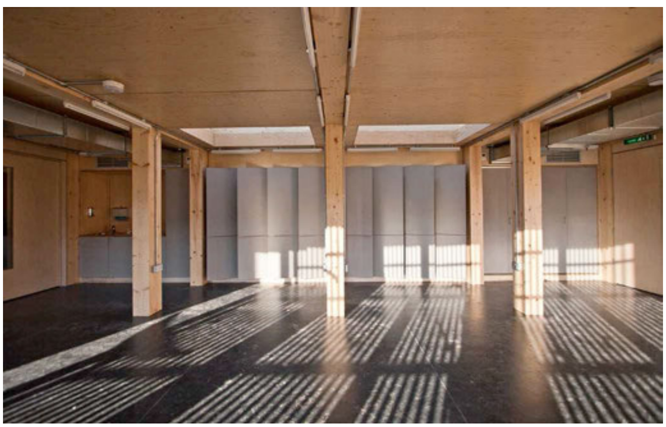


225mm thick SIPs roof cassettes were hand lifted, aligned and screwed to the frame; The entire envelope was covered in an EPDM waterproof rubber membrane to provide the watertight layer; A floating galvanised steel roof structure and finish and rooflights are installed;


The mural graphic panels are bonded to the EPDM membrane without breaching the rubber; A galvanised steel mesh, charred spruce cladding and security/ solar shading doors are fixed to the walls and windows using battens and screws; Modular Welsh oak laminated windows are installed into open bays and fixed to posts; Galvanised steel conduit, sockets and light fittings are surface fixed internally; A birch plywood storage wall is fitted along the back wall;



Outcomes

The ERC successfully integrated a complimentary range of components to work together to create a simple layered construction that evoked the history and wildlife of the site. The SIPs panels were lightweight and complimentary to the box section components but they are not sustainable and replicable as a low-tech construction solution. Further technical outcomes were revealed during this prototype for consideration in the design of future Ty Unnos buildings:

- The completed system was not manufactured locally;
- The choice of end-grain bolting was successful and aided the simple, no crane, construction process (frames and panels erected in 10 days);
- The manufacturing of the end-grain bolting detail is not low-tech - is this repeatable in a less equipped workshop?
- The standard sizes of box post and beam were used , although floor and roof beam sizes were increased to a length of 7.2m for ease of construction and transportation. Beams were propped at the 4.8m point by box section posts;
- The level threshold detail was dealt with by using the natural fall to the site, but a large cutting was required to allow for underfloor ventilation - this still needs refinement for future projects;
- The principle of a simple layered construction worked very well, but were there too many layers?
- Exposing internal finishes creates a difficult time consuming and costly construction process (especially when built in the winter) to avoid weather damage;
- Fire protection combined with hard wearing varnish for internal finish worked well;
- While services were exposed in this building, the construction highlighted potential problems with services integration on other types of building;
- Oak laminated windows successfully re-implemented previous research into Welsh wood windows using small sections and lengths of local hardwoods;
- Charred timber used ungraded, low value softwood. The building was completed 3 years ago and the cladding is still protected by its charred finish, but how replicable is this to reliably manufacture and specify?

PROTOTYPE 4

Ty Unnos longhouse

Introduction

Following funding won through a Technology Strategy Board (TSB) competition for the low impact building systems launched in 2009 a fully developed and regulatory compliant 2 bedroom house was designed and built as the focal point for testing the complete integrated system using a local supply chain. The commission was won through an open design competition conducted by the Welsh Future Homes project partners and was opened by the Welsh Minister for the Environment in August 2010.

Objectives

This was the final prototype to test the refined Sitka spruce components. The primary focus was on the construction of an affordable dwelling using a completely integrated system entirely from the local supply chain:

- an affordable house meeting Welsh Government Design Quality standards
- a raft foundation and minimum 150mm requirement of timber structure above ground level;
- a 2-storey structure with loft;
- infill panels with ground to roof OSB racking resistance;
- softwood and steel inner connecting sleeves with steel brackets and plates;
- Welsh chestnut low energy windows; and
- green Welsh chestnut cladding.
- longhouse principles of form and space

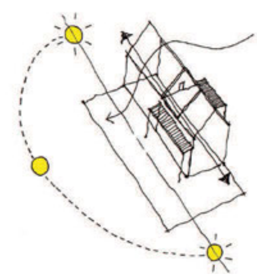
Model used to explore the longhouse form in terms of spaces, materials and construction

Building Simply

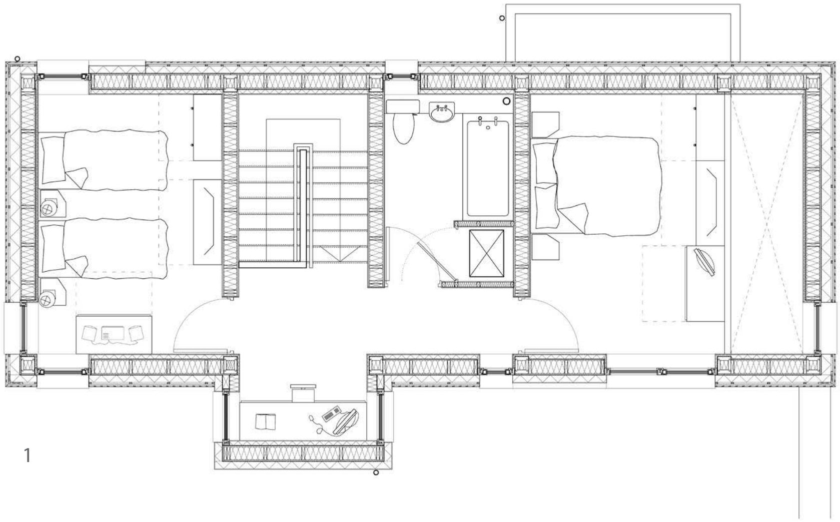
The development is the result of a partnership between BRE Wales, the Welsh Assembly Government, The Works at Blaenau Gwent County Borough Council and United Welsh Housing Association. The overall aim of the project was to stimulate the development of a low carbon built environment in Wales but also to kick-start a 'green' economy. Funded by the Heads of the Valleys Programme and The Works, this longhouse was designed as part of a 'mini community' comprising three other sustainable homes all costing between £1,200 – £1,600 /sqm to build (average cost of social housing Code 3 is £1,200/sqm).

This proposal was a development on a prototype 1 house type and the Smithsonian design while inspired by the local context of Ebbw Vale and the wider context of Wales, providing a model of economic, social and environmental sustainable housing for The Works site. The primary concepts were inspired by:

- The longhouse - The design of the house is a re-interpretation of the traditional Welsh longhouse vernacular for the 21st century. The linear house looks south across its garden to the hills beyond with both access and internal circulation along this edge and rooms located along and at the ends of this axis.
- Simple forms - Drawing on the simple forms of Welsh barns, longhouses and farm buildings, the house aims for a simplicity of planning, materials and detailing. A restrained but elegant palette of vertical timber cladding, white render and standing seam roof are used to develop a contemporary interpretation of traditional vernacular buildings.
- Composition - The addition of colour to a terraced house is a common way of personalising Welsh Valleys housing, with examples close to the site in Ebbw Vale. Red render was added around windows and the northern dining bay to add individuality, that would differ on a larger development.
- Ty Unnos - As well as the construction system being prototyped the design evoked the sense of the Welsh tradition of building 'a house in one night' with several original Ty Unnos houses existing in the Ebbw Vale area.



Concept of longhouse principles: route,linear arrangement of rooms and frame and south facing



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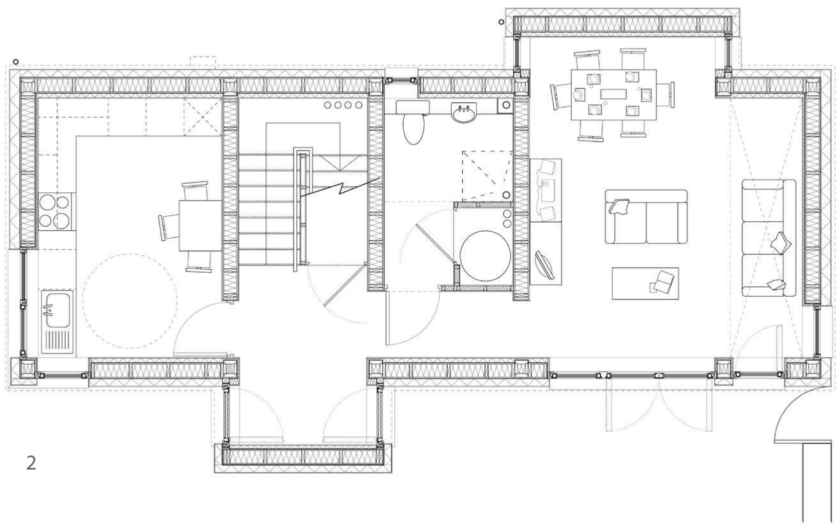

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1 Ground floor plan
2 First floor plan

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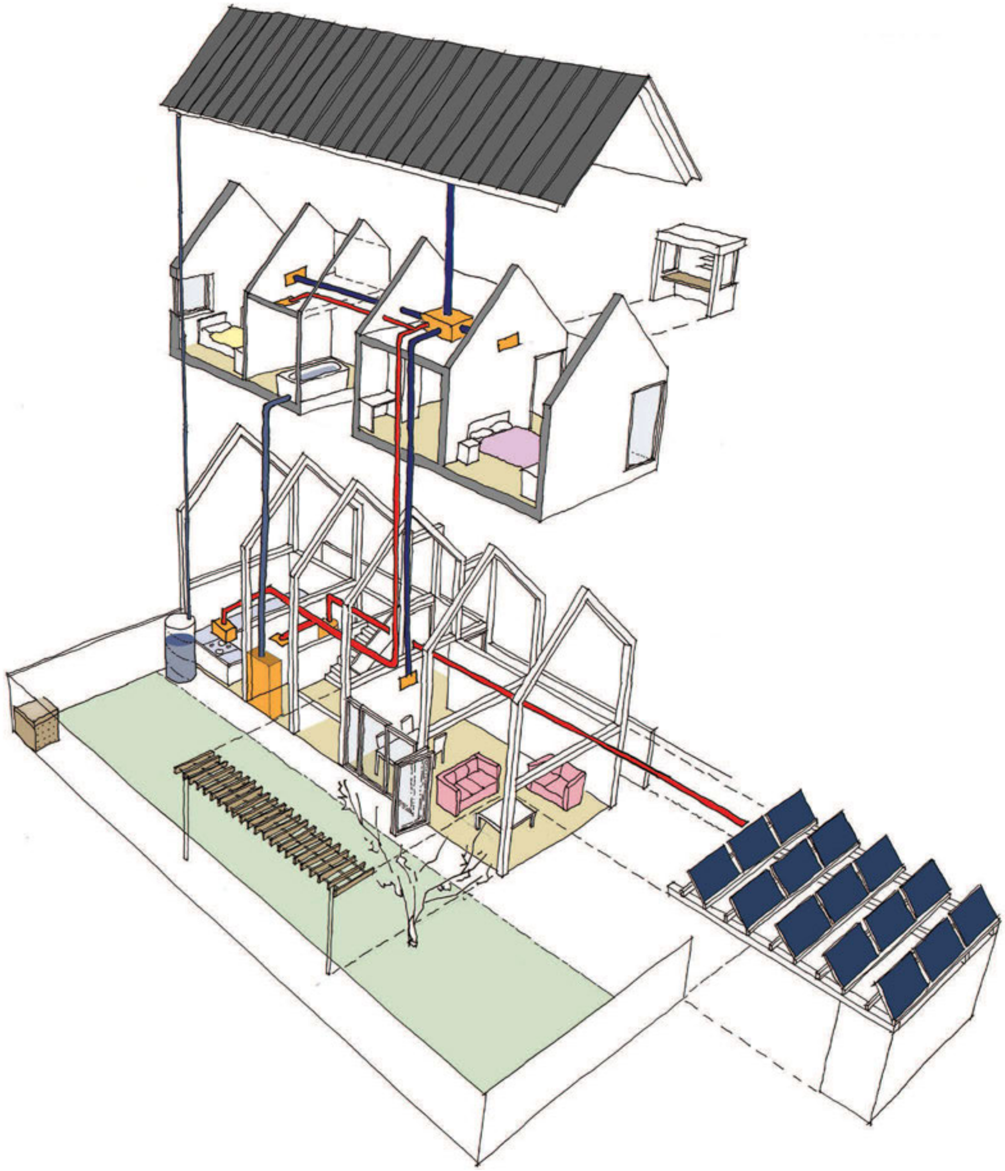
3

1 South elevation
2 North elevation
3 East elevation



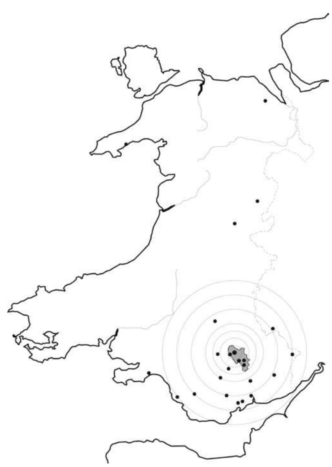
Exploded axonometric of the
environmental performance

Regionalism and environment

It was agreed early on between DRUw and Blaenau Gwent County Borough Council that the design would aim to be a locally made house using local supply chains from within the Ebbw Vale or Blaenau Gwent area and then progressively looking wider as required. Approximately 80% of materials, suppliers, manufacturers and products were sourced successfully within a 40 mile radius of Ebbw Vale.

The longhouse was further inspired by Passivhaus energy performance standards, but adapted to use local products and suppliers. The resultant design proposed the following energy performance measures to reach a Code for Sustainable Homes Level 5 with an emphasis on a fabric first approach:

- Ground floor U value 0.07 W/m2K, walls U values 0.1 W/m2K, roof U value 0.11 W/m2K;
- 0.95 W/m2K Welsh developed, sweet chestnut triple glazed, thermally broken, double sealed windows;
- Total energy demand for space heating and cooling <15kWh/m2/yr using a mechanical ventilation with air source heat recovery system (MVHR);
- Ty Unnos system details designed to be airtight to achieve air permeability of 0.3m3/hr/m2 at 50 Pa as well as reducing thermal bridging;
- Lighting: 100% LED and low energy spotlights throughout;
- A++ labelled white goods;
- 4m2 Solar hot water array to reduce water heating demand in summer;
- Water consumption less than 80L water per person per day through the use of reduce flow taps and shower, and dual flush WC's;
- Rainwater collection for garden use ;
- Supply chain investigation predicts A+ materials will be used throughout.

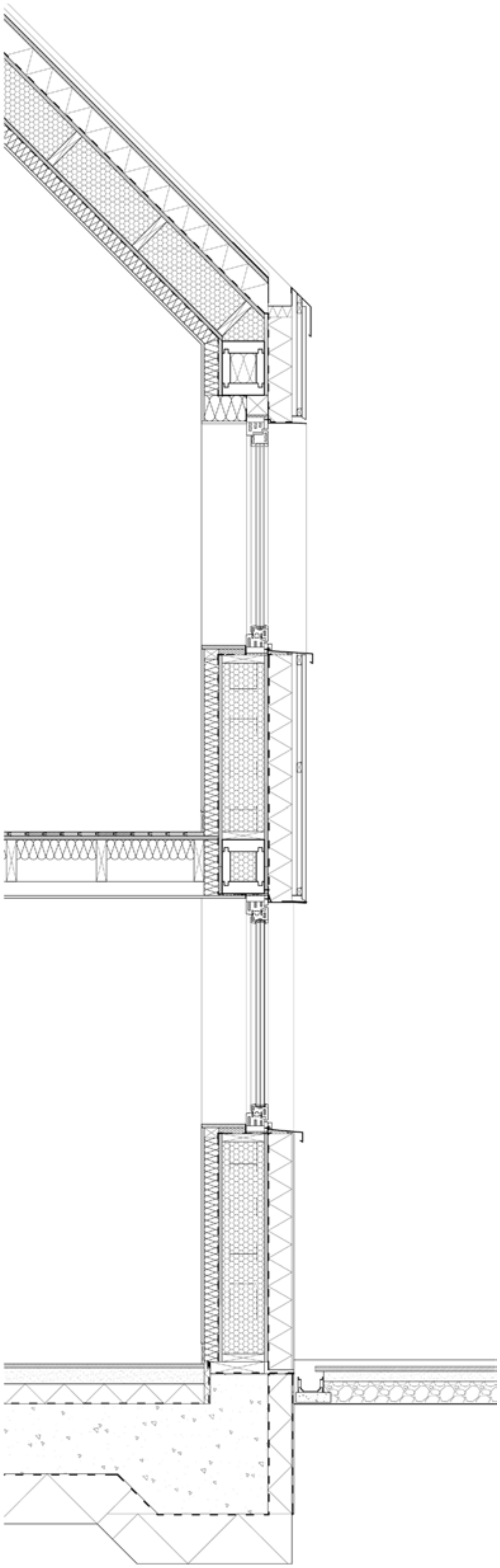


Location of the material and product supply chain

Tectonics

The construction system was ideally suited to the simple longhouse form, allowing an optimum configuration of Sitka spruce frames to create a linear 'tube'. The module changed along the length to reflect the internal spatial configuration using 1.2m, 2.1m and 3.0m modules all 4.2m wide internally. The ground floor height was limited to 2.2m to work with standard board and timber sizes, while the 2 first floor bedrooms were opened up to the ridge with a 'crog loft' created above the stairs and bathroom for storage and plant. Due to the extremely low U values and air tightness requirements, the construction process was more complex than the other prototypes with significantly more layers to floor, walls and roof sandwiching the structure deep within the 425mm envelope thickness.

Construction section through southern wall incorporating the multi-layers of frame, insulation and membranes



A raft foundation with 250mm underslab XPS insulation and 150mm upstands to receive the box section frame was prepared; The ground floor 270x210mm box section posts and beams were erected and fixed using steel angle brackets and plates to a 270x60mm continuous sole plate. Full bay, prefabricated open-panels with solid spruce studs and OSB were fitted from the outside and screwed to the posts. The internal OSB was fitted later overlapping panels and frame to provide shear resistance;





Ties beams between principle frames are connected at intermediate floor level and eaves; The first floor and roof structure was craned into position to engage with the spruce box section insert connectors. Full bay infill panels for walls and roof were also installed; Open-panels were used to construct the porch and dining bays to and the envelope was wrapped externally in breather membrane and internally lined with a Proclima Intello membrane;

Welsh chestnut low energy windows and doors installed; Warmcel insulation was blown into all external panels and rigid wood fibre insulation fixed externally to the roof pitch and first floor walls; Aluminium linings applied to surround openings and Rockwool external insulated render system applied to ground floor walls;





Standing seam metal roof installed and interior battened out to create a service void before finishing with taped and skimmed plasterboard;Timber cladding installed to first floor elevation and solar hot water panels installed; Rainwater goods, and external finishes completed.

Outcomes

The Sitka spruce components and construction sequence reflected the intended simple contemporary longhouse form, although the environmental requirements potentially suffocate the timber components behind a white plasterboard lining. This was the first construction of a 2-storey structure using the Sitka spruce components, although the engineering led to a hybrid of systems combining box section frame with open panel construction suggesting that either the frame or panels alone would suffice. Construction was quick and efficient with the frame and panels erected in 5 days with the remaining construction only extended by the number of layers required to meet the energy performance requirements. Other technological observations are as follows:

- built on a raft rather than pad or strip foundations - worked well, but excessive amount of concrete and slightly awkward kerb details to create 150mm Building Regulation requirement;
- prefabrication of roof beams already as a 'truss' greatly helped construction;
- softwood and steel insert connectors developed from hardwood connectors on Smithsonian worked well seemingly with very little settlement, but not good with thermal bridging or filling box beams with insulation at each junction;
- low energy aspects pushed the system to its limits;
- thermal bridging not very good due to repetitive box section posts and beams;
- The beams between frames between each room and the OSB bracing from ground floor to eaves were time consuming and prohibited services running with in the floor zones across the house
- Develop the ladder beam further to replace solid stud and reduce weight and thermal bridging effect.

FINDINGS

Findings

The research has shown that local, under utilised, low value Sitka spruce can be used in the design of contemporary and sustainable domestic scale architecture in Wales. Through a re-engineering of the timber, a series of modular responses have been made that show potential to use homegrown Sitka spruce and other softwoods, as an alternative to importing Scandinavian or North American timbers.

More specifically the system has been demonstrated to be efficient, sustainable and simple in the design of small span and domestic scale buildings. The weighting of components, the layering of the building envelope and building design have all contributed to the simplification of the building process eliminating large machinery and reducing the construction time on-site. The system, as demonstrated in this research, is based on:

- a modular glue-laminated post and beam structure, maximising the use of readily available, standard lengths and sections of Sitka spruce;
- a modular panel system based on spruce or other softwoods that can provide flexibility in use and adaptation in the future through wall, window and door positions;
- reduces the need to defect cut any spruce for laminating;
- using basic mechanical fixings such as brackets, plates and screws, to maximise the potential to disassemble and recycle/ downcycle the structure later.

In all three building prototypes an elemental and additive process to design and manufacture has been observed that begins with local materials in their standard, modular format and contributes with other elements to form the complete building structure and envelope. While each prototype is spatially different, each design reflects the tectonic proportions of the material and modules that have been inspired by the local context and vernacular.

The system does, however, have some technical limitations that need to be overcome to reduce cost, improve tolerances and flexibility and refine details for future projects and possible commercialisation:

- the box section frame and panels require further refinement when used together to reduce structural redundancy and repetition;
- the fabrication of the frame connections require less complexity and better thermal performance;
- the manufacturing process should be reviewed to increase production and reduce costs;
- the spatial configuration and distribution of services should be refined to avoid limitations caused by the box section frame.

Further work

The research into the additive use of Sitka spruce in contemporary Welsh architecture continues, with large-scale spans being explored for use in school and public buildings and window and door cassette systems, that are complimentary to the current components and allow for simple replacement and maintenance in the future.

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1 proposed Caban Unnos
2 Swallow Hill house
3 Glan Gors Affordable housing, Elements
Europe

Wider impact of Ty Unnos

Following the initial Ty Unnos research and the first prototype stage, dissemination of product and design publications led to interest in the components for use in a range of projects that were developed in parallel and following the outcomes of this research document.

Elements Europe, a modular bathroom manufacturer in mid-Wales has developed the system to work as a volumetric method for the construction of affordable housing on a commercial scale., while a number of publicly and privately funded clients have approached various members of the research team to build one-off projects using a wider design team. This has increased the impact and knowledge of the Ty Unnos system to a wider audience including architects and clients.

The following list includes all projects proposed, ongoing and completed that have used the Ty unnos components as detailed in this document:

- Smithsonian Pavilion, Washington DC, 2009
- Llandelga cycle lodge, Llandegla, proposed 2009
- Environmental Research Centre, Ebbw Vale, 2010
- Ty Unnos longhouse, Ebbw Vale, 2010
- Glan Gors Affordable Housing, Dolwyddelan, North Wales, July 2010
- Caban Unnos, Pembrokeshire Coast National Park, ongoing
- A Rural Studio, The Old Sawmill, Tregynon, ongoing
- Leighton Arches, Leighton Road, Welshpool, September 2011
- Forestry Centre, Rosliston, Swadlincote, Derbyshire May 2010
- Swallow Hill, Mynydd Du Road, Treuddyn, North Wales, March 2012
- Living Solutions trial structure, Cowdenbeath, Scotland, April 2012
- Ty Tyfu, Llanarthne, Carmarthenshire, October 2012
- Canolfan Tyfu at National Botanic Gardens of Wales, proposed 2012
- Blaengors Rhydargaeau , Private house, proposed 2012