WINSTON CHURCHILL MEMORIAL TRUST

Lessons in House Building

Japan | New England

Contents

Executive Summary

This document reports on my 2018 Fellowship to Japan and New England to research modern methods of house construction, generously funded by the Winston Churchill Memorial Trust. The purpose of the Fellowship was to gather lessons from house builders known to excel in certain key areas, namely construction using off-site methods, the use of timber as a primary construction material, and the production of energy-efficient homes. The intention of the Fellowship was to demonstrate the benefits of investing in high-quality production processes and materials, resulting in high-performance houses.

The report begins with an examination of the key issues, and why Japan and New England were the chosen destinations for the Fellowship. The main body of the report is presented as a series of case studies from house builders and designers in central Japan and New England, USA. Key findings from each case study are presented at the end of each section.

Case studies from Japan are divided into two main groups – those of large, volume house builders employing extensive off-site construction techniques, and those of smaller builder / architects employing more traditional post and beam techniques, and working in the field of energy-efficient design.

It was found that these larger Japanese house building companies have a streamlined and highly efficient off-site construction system, producing thousands of homes each year and utilising Building Information Modelling (BIM) technology to streamline their process. Material use has been developed over a long period and is aligned with the capabilities of their existing production facilities. Although there is a cultural preference for timber construction, the majority of houses produced by these volume builders are modular steel frame.

With regards to performance and energy efficiency, it was found that the larger Japanese house building companies undertake significant amounts of research and development into certain areas of performance. However, energy-efficiency did not appear to be a driving issue, whereas fire resistance and seismic protection measures are highly valued.

I met with smaller Japanese building firms and architects who are very engaged with energy-efficiency, collaborating and learning from each other. The smaller building companies use more traditional on-site construction with an element of off-site preparation, and a strong awareness of materials and component sourcing. There was a particular awareness of foreign-made high-performance components, and their suitability for the Japanese climate.

Case Studies in New England are also divided into two groups –the first being the provision of multi-home social housing, which excels in energy performance by attaining Passive House certification. The second group was design and build firms providing houses to private clients and small developers, using varying levels of off-site construction. As with most of North America the majority of projects I visited used timber as the primary construction material.

The level of off-site construction varied considerably between the New England case studies. I found a particular focus on off-site in the companies that offer combined ‘design and build’ services, but less so in larger architect-designed projects. Strengthening the link between design intention and construction was a common theme throughout the New England part of the Fellowship, and as shown in the case studies, it has been tackled in a variety of ways by different firms.

It was generally found across the New England case studies that there was a strong motivation to achieve energy-efficient buildings. Most of the companies I visited were engaged with, or had achieved, Passive House-certified projects. Some companies were taking this a step further and looking at more demanding sustainable-building criteria.

At the end of the report the conclusions and key lessons are outlined along with recommendations for application in the UK context:

- Investment in the creation of off-site manufacturing facilities, along with related technology and skills training
- The development of off-site orientated Building Information Modelling to streamline the Design for Manufacture process
- Encouragement of timber use in the construction of new housing
- Funding made available for the research and development of UK-specific products that are currently designed and manufactured abroad
- An increase in the base thermal performance levels in the building regulations
- Encouragement of early collaboration between designers and contractors in order to achieve high-quality construction within project budgets.

As a result of my Fellowship, I am convinced that the adoption of some or all of the above recommendations would significantly benefit the UK in terms of providing more high performance energy-efficient housing and significantly reducing the time to construct new homes- both of which are problems that need to be seriously addressed in the UK.

This report is designed to be of interest to architects, builders, developers and policy-makers. As I have used terms that may be unfamiliar to some readers I have included a glossary section on page 6.

Acknowledgements

I must first thank the Winston Churchill Memorial Trust for allowing me the opportunity to travel to Japan and the USA, meeting wonderful and inspiring people. My family and friends helped me in numerous ways in preparing for the Fellowship. My thanks also to my employer MAKAR for allowing me the time away from work for both the Fellowship, and for the writing of this report.

It would be impossible to thank all of the people who have been so generous with their time, knowledge and insights throughout this process. Even before leaving on my travels the list was lengthy, and it continues to grow since my return. Many thanks to all of you.

About the author

I am an architect and Passive House designer based in the North of Scotland. Much of my professional career has centred on the delivery of healthy, ecological homes using innovative off-site timber construction.

The aim of the company I work for is to produce healthy, low-impact living environments whilst supporting the local economy and sustainable management of the environment. My job involves the creation and optimisation of house designs to suit a standardised ecological construction system using Scottish-grown timber. In the past ten years my employer has increasingly employed off-site construction methods with the ambition to improve build quality and working conditions.

My academic background includes research into the timber construction systems used in house building in Scotland, and more recently in gaining certification as a European Passive House Designer.

From my professional background I have a long standing interest in the three themes of this Fellowship, namely off-site construction, use of timber, and production of energy-efficient homes. In the next section I examine why they are important themes to explore in the context of house building.

Glossary

On the following pages I have outlined my understanding of the technical and possibly unfamiliar terms used throughout this report.

Air-tightness
This refers to the amount of air that can escape through cracks and joints in the envelope of a building. Air-tightness has been identified as a major factor in heat loss, through the escape of warm internal air. Conversely, as modern homes are built to be more 'air-tight', it has been found that without adequate renewal of internal air, the quality can be seriously compromised in regards to CO_2 levels, pollutants and moisture [Sharpe, Shearer, Foster 2014].

Balloon framing
Balloon framing refers to the approach to building whereby a full height wall is erected, normally using a stud wall, or 2 by 4 type frame. The intermediate floor is then constructed within the 'balloon' envelope. This type of construction can make it easier to air-seal the envelope as opposed to platform framing.

Building Information Modelling (BIM)
The production and use of a three-dimensional computer model of a building. There are many 'levels' of BIM modelling, which can go as far as including information about mechanical servicing of the building.
Although most BIM models are currently used during the design stages, there is a move to include the BIM model in the construction phases, and even when the building is in use for the purposes of maintenance.

Cross Laminated Timber | CLT
An engineered timber product that consists of layers of kiln-dried timber glued at 90 degrees to the previous layer. This produces a strong, structural panel, which can be used for floors, walls and roof, with openings for windows, door and services pre-cut in the factory. In recent years there has been a number of high profile high rise CLT buildings in the south-east of England.

Fabric-first
This term is normally used to describe prioritising the performance of the 'fabric' - the walls, roof, floor and windows – of a building to reduce energy use, before reverting to the use of technology or equipment to reduce energy usage. This principle is often used in Passive House design, whereby it is argued that investing in the fabric of the building is paid back in lower energy bills over a period of time. Often a calculation can be undertaken to show how long it will take to 'pay off' an additional amount of insulation or a higher performance product.

Lean
Lean management is very much associated with the car manufacturing industry and Japanese business models in which supply chains are tightly controlled, materials are delivered 'just in time' and processes are pre-planned to be as efficient and smooth as possible. Perhaps most importantly, Lean principles ask what value is added at each stage of a process, and tries to eliminate any 'wasteful' processes, within a culture of on-going improvement.

Mechanical Ventilation with Heat Recovery | MVHR
Whole house ventilation systems are routinely installed in low energy and air-tight new builds, whereby stale, moist air is removed from the house and replaced with fresh air. An MVHR system allows the warmth from the outgoing air to be transferred to the incoming air in order to reduce the heat loss that would take place through the process of ventilation.

Modern Methods of Construction | MMC
A broad term, which encompasses the ambition to build quicker, cheaper and with better results. The main focus of MMC is off-site and factory-based construction, which is seen to deliver these ambitions.

Modular
Three-dimensional building components, often, but not necessarily, of a standardised design. Modular builds are sometimes referred to in relation to self-contained units, as opposed to volumetric which more often applies to a larger building constructed of several three-dimensional components.

Off-site
A series of excellent videos about off-site construction in Scotland can be seen **here**.
Off-site construction refers to the method of building the components of a building away from their final installed location.
Most commonly this means medium sized components such as windows and doors, and increasingly is referred to for larger components such as walls, roof trusses and three-dimensional modules.
Many of the advantages of off-site construction can be referred back to the '1-3-8' rule in shipbuilding, whereby it is said that a task that would take eight hours to complete in-situ on the hull of a ship, can be reduced to three hours if undertaken off the hull, but at the shipyard, and reduced further to one hour in a fully equipped workshop [Kieran 75].
It is generally agreed that to refer to a building constructed 'off-site' it has been substantially completed before transportation and assembly.
An Industry Review in 2013 identified 'off-site' as when the value added on site is less than 40% of the overall value at completion.
See also Prefabrication.

Open panel | Closed panel
Panelised systems are generally one of two types – open or closed. Open panels are framed out using timber such as spruce. The panels are sheeted on one side to provide structural racking. Panels are erected like this on site, and the process of insulating, sheeting and cladding takes place on site.
Closed panels are generally sheeted on both sides and insulated before being sent out to site. Following this, it is possible to install other components in the panels before going out to site: Windows, doors, cladding, internal sheeting, plumbing, electrical and ventilation services are all possible to include. This depends on the design and specification of the project, the facilities available to the contractor, and whether the extra work off-site will have a beneficial time or cost-saving effect on the project overall.

Panelised
This form of construction is very common in the UK, particularly Scotland. The building is formed by a series of large panels comprising floor, walls and roof (or a hybrid with another system such as floor slab and roof trusses). Panels are generally formed off-site, or adjacent to the building site. Depending on their size and weight, panels are installed by hand or by using lifting equipment. The panels for a typical house can be erected in just a few days. If the windows, doors and cladding are already installed as well then a house can be weather-proof inside of a week.

Passive House
A voluntary certification for all building types based on rigorous criteria for energy efficiency and thermal comfort. Promotion and certification is controlled by the Passivhaus-Institut, which was founded in Darmstadt, Germany in 1996. Certified buildings must demonstrate extremely low energy requirements for space heating. The criteria also covers internal air quality, perceived thermal comfort, overheating risk and primary energy consumption.

Passive House Planning Package | PHPP
The Passive House Planning Package (PHPP) is an Excel-based planning tool for use during the design of a Passive House. It contains numerous calculations based on input by the designer in regards to the specific project and its location. The PHPP is used to demonstrate compliance with Passive House criteria.

Platform framing
Platform framing differs from balloon framing in that the walls are built to a single storey height, and the intermediate floor is constructed on top, giving a platform to work off for the next storey walls. This method makes detailing for air tightness more difficult, but it can mean easier detailing to avoid fire spread from floor to floor.

Post and beam
In this report 'post and beam' refers to the use of large section timber components joined to form a structure. Traditionally Japanese carpenters would join the timbers using complex woodworking joints. Today this technique is still employed, although the joints are often formed by machine rather than by hand.
Post and beam construction is also found in traditional New England construction in a different style, but similar application.

Prefabrication
The off-site fabrication of construction components prior to installation on the building site. Most commonly referred to in the context of factory production of building components, although it could also refer to fabrication in temporary facilities on or adjacent to the site. Prefabrication takes place on a range of scales, from small components such as nails and fixings, to easily handled windows, doors, structural beams and columns, pipe and ductwork, to much larger components requiring specialist lifting equipment – this would include larger glazed units, cladding panels, panelised frames and volumetric units restricted only by the dimensional limits of the transport method. The latter is what is often referred to as Modern Methods of Construction

Thermal Bridge
A thermal bridge is an area of higher thermal conductivity than the area around it. It can be measured linearly (such as the perimeter of a window installation) or as a point (such as a screw fixing through an insulation layer). In buildings this causes heat loss at a greater rate than the surrounding area, and has the potential to cause condensation and mould growth, as well as a general reduction in thermal comfort. Ultra-low energy building specifications, such as Passive House, attempt to eliminate thermal bridges in their construction entirely.

Timber construction
Building which uses a significant proportion of timber for structural and framing purposes. Common types of timber construction include balloon framing, platform construction, post and beam, solid timber panels and cross-laminated timber panels.

U Value | R Value
The U value of a building component is measured in W/m^2K (the alternate measure R value is used in the USA), and it represents the thermal transmittance value. Ideally building components such as wall or roof have a low U value, in order to lose as little heat as possible by thermal conduction. Building regulations state the maximum acceptable U Value of components such as floor, walls and roof.

Units
Japanese term used to describe three dimensional off-site construction. A unit is typically dimensioned to fit on a standard articulated lorry, and a typical Japanese house is constructed of around 10 units joined together. The units are often partially clad, and internally lined with pipes and electrics installed in the factory prior to transporting to site.

Volumetric
The forming of three-dimensional or modular building components off-site. Three dimensional building components are most often steel or timber framed, and often include services and fixtures.

Wood fibre insulation
There are several wood fibre insulation products available on the market, largely produced in France, Germany and Austria. In general the product is available as a semi-rigid board or batt, and can be used externally or internally for insulation purposes.

Introduction

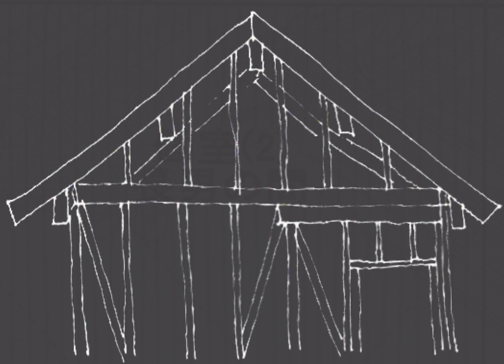
I applied to the Winston Churchill Memorial Trust under the category of '*New Approaches to Social and Affordable Housing*'. My Fellowship proposal was to visit two places that are known to excel in three particular fields, which if brought together could provide a useful set of lessons for architects and builders in the UK in achieving the better quality, sustainable homes we aspire to.

The three themes of the Fellowship are:

i. The building of homes using off-site construction methods;

ii. The use of timber as the primary construction material; and

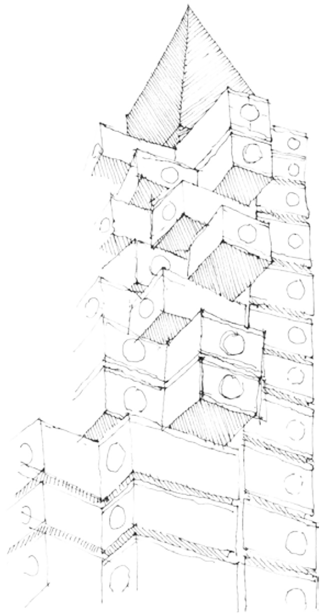
iii. How low-energy performance homes are achieved using the two approaches above.



Timber frame
Obuse, Japan

Why off-site?

The building of homes using off-site construction methods



Nakagin Capsule Tower
Tokyo, Japan

There have been many calls for change to the construction industry over the past quarter century, in particular to consider the benefits offered by off-site construction.

Despite off-site being promoted in many government reviews including Sir Michael Latham's 1994 '*Constructing the Team*' and Sir John Egan's 1998 '*Rethinking Construction*', it appears to remain difficult to achieve in practice. As recently as Mark Farmer's 2016 review '*Modernise or Die*', a lack of uptake of prefabrication was identified as a problem, along with a lack of research and development in the construction industry. Included in the Farmer recommendations was for the UK government to act as an initiator in promoting training, R&D and investment in off-site manufacturing facilities.

The main advantages of off-site construction are generally agreed to be the following:

- Improved worker safety – potentially reducing the time spent working at height or out in the elements. This is particularly relevant in the wet UK climate with its short winter daylight hours: A factory can be heated, dry and well-lit all year round.
- Quality assurance – components manufactured in a controlled environment can be more easily checked for quality before site assembly. Quality control can be tricky to carry out on site, particularly in hard to reach places or when workers are outside in the elements.
- Tackling industry skills shortages by reducing reliance on wet trades such as brick-laying. The off-site industry instead requires skilled fabricators, ideally with skills in using automated machines and computer-aided design.
- The potential for work to happen concurrently in various locations rather than sequentially on site. This serves to reduce the overall contract time as well as site time, which in turn reduces noise and disruption to neighbours.
- The location of factories can be related to workforce availability and nearby transport links.
- Material waste can be controlled and reduced through careful planning within the factory environment.

It was announced in July 2018 by the UK government that certain government departments will '*adopt a presumption in favour of offsite construction by 2019…where it represents best value for money'*. However, despite being recognised as an improved construction method, there remain significant barriers to its uptake: In 2015 it was reported in research by Homes for Scotland that *'while local authorities and housing associations intended to promote the use of off-site construction with their specification, it was often reconsidered when the costs became clear. In particular, it was understood that the range of design specification requirements for affordable housing made it difficult to achieve benefits in terms of the economies of scale achieved in delivering standardised products.'* [17]. Further to this, a report by Clyde and Co. in 2018 identified *'capital costs and lack of relevant knowledge within their organisation'* as the top two reasons survey respondents were hindered from adopting off-site methods [4].

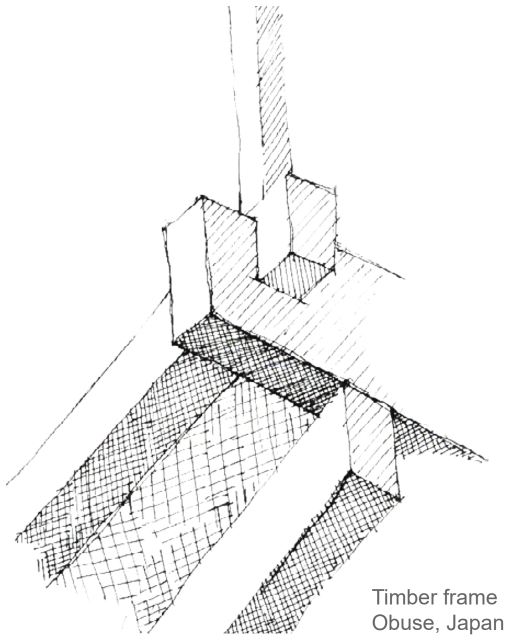
It appears to be clear that in order to provide developer clients with off-site solutions that are best value for money we need to learn from what others are achieving successfully.

Why timber?

Constructing homes using timber as the primary construction material

Timber is known to be a sustainable building material, with the ability to sequester carbon if it sourced from sustainably-managed forests. In countries with forestry stock, it is an obvious construction material to consider using, and it affords many benefits to both the construction process and the built environment.

Recognising the benefits of timber construction, many countries have implemented policies favouring timber as the principal construction material in new buildings including Finland and Sweden. In 2010 Japan implemented the '*Act for Promotion of Use of Wood in Public Buildings*'.



Timber frame
Obuse, Japan

The UK does not currently have a policy to promote timber use in construction. In Scotland the majority of new homes are built using timber frame with a block or brick external skin normally constructed on site. In England however, the use of timber framing reduced drastically during the mid-1980s after adverse publicity regarding the risk of rot and fire. It has since been demonstrated that with suitable detailing and competent workmanship timber construction can last for many decades, although the proportion of timber framing in English house-building remains low [Davies 67].

The benefits of timber construction include the following:

- The production of timber for use in construction has a far lower embodied energy than that of steel or concrete. Additionally, timber has a high strength to weight ratio, and its lightness makes it an ideal material for off-site construction and transportation [Hairstans 7].
- There are many engineered timber products available for use in construction, including large-section timber components which are glued, nailed or dowelled together to produce beams, columns and panels. There is also a huge variety of boards manufactured from timber by-products such as timber particles, strands and fibres.
  Depending on their properties these products can be used for racking, cladding, sheathing and insulation.
- It is common to use treated timber in construction, although it is possible with careful detailing and the use of the appropriate species for a large proportion of timber treatment to be avoided. If achieved, this benefits the construction process and the built environment with a reduction in off-gassing.
- Timber is hygroscopic, in that it can absorb and release moisture. If used as part of a 'breathing' construction, this allows the fabric of the building to be vapour permeable. This is particularly important in modern, air-tight houses, which are known to suffer from moisture build-up if they are inadequately ventilated [Sharpe].

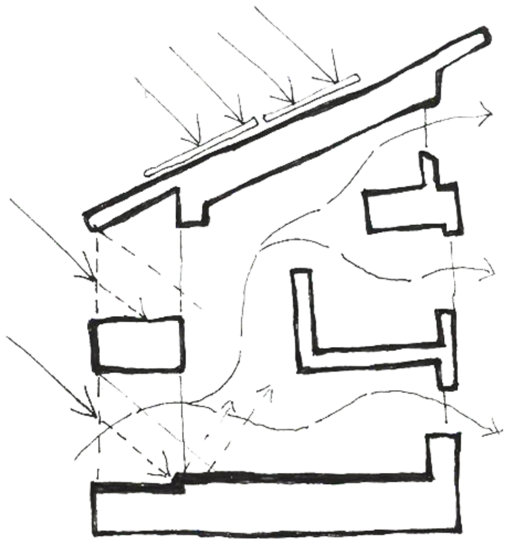
There are a great number of advantages in using timber construction. With the growing UK forest resource it makes sense to consider ways to use timber as a primary construction material, and to learn from nations that already utilise timber a great deal.

Why energy-efficient performance?

Homes that require significantly less energy to heat and run than typical new builds

The UK has legally binding targets to reduce greenhouse gas emissions by at least 80% of 1990 levels by 2050 [Climate Change Act 2008]. Despite this, the UK has a recent history of failing to uphold challenging energy standards. Most significantly, the UK government announced in 2014 that it would reduce the scope of the Code for Sustainable Homes and UK Zero Carbon Homes, and instead integrate energy-efficiency policy into the Building Regulations.

The quality and performance of buildings relates back to several interconnected issues including greenhouse gas emissions and tackling fuel poverty. The high quality required to achieve an energy-efficient building can be linked to the potential longevity of a structure, and the level of maintenance required to keep the building in good condition.



COMMA House diagram
University of Tokyo, Japan

It has been reported by the UK government that the energy used domestically in 2017 accounted for 28% of the total energy used in the UK [21]. It is therefore a significant contributor to greenhouse gas emissions. UK building standards already specify baseline standards for thermal performance and air-tightness for new build homes. However, there exists other voluntary energy standards, such as Passive House, that have far more demanding criteria for reducing space heating demand. As an example, a typical UK house might use 140kWh/m^2 per year for space heating, whereas a Passive House requires that no more than 15kWh/m^2 per year. [Passivhaus Trust UK 12].

At current energy-use levels it remains that 2.25 million households were reported to be fuel poor in 2016 [UK Government], whereby their required fuel costs were above the national median, and that the cost of adequately heating their home would push their remaining income below the official poverty line. As such, many occupants are forced into a situation where they cannot afford to heat their home leading to health issues caused by damp and cold.

Additionally, and even for those who have the means to adequately heat their home, older buildings often suffer from draughts and cold spots that affect thermal comfort and can cause maintenance problems. We have a relatively old housing stock compared with much of Europe [UK Government 24] and if not adequately maintained this can lead to environmental and structural problems. It is vital that the new homes we build are built to last without the typical short-term thinking we have come to expect in the procurement of new house building.

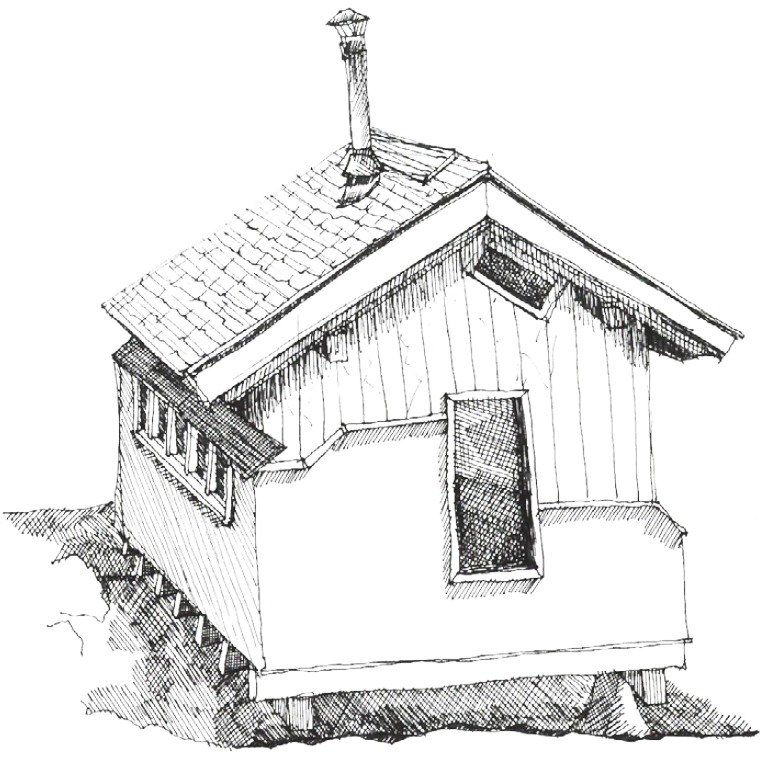
Although new housing in the UK is built to energy standards defined by the building regulations, there is great scope for increased and improved standards. Policy-makers must be persuaded to incentivise more demanding performance, and to evaluate the increased initial cost against the health and longevity of a home and its occupants for years to come.

Conclusion

Despite the obvious benefits, it could be argued that it is not feasible to employ progressive construction methods, or invest in high performance energy-efficient homes within the typical budgets available for affordable and social house building. However, we have many reasons in the UK to overcome this typical short-term thinking that has come to define our provision of new housing. Our construction industry desperately needs reform, we need to make use of viable resources, and we are legally obliged to reduce greenhouse gas emissions over the next 30 years.

We already have a limited number of examples of progressive projects in the UK, which includes the Commonwealth Games Athletes' Village delivered by CCG (OSM), Urban Splash's custom modular developments, Legal and General's single-person modules, and kit systems by contractors such as Laing O'Rourke and Stewart Milne. However, in order for well-constructed, high-performance buildings to become mainstream we must take inspiration from other countries who are tackling similar challenges.

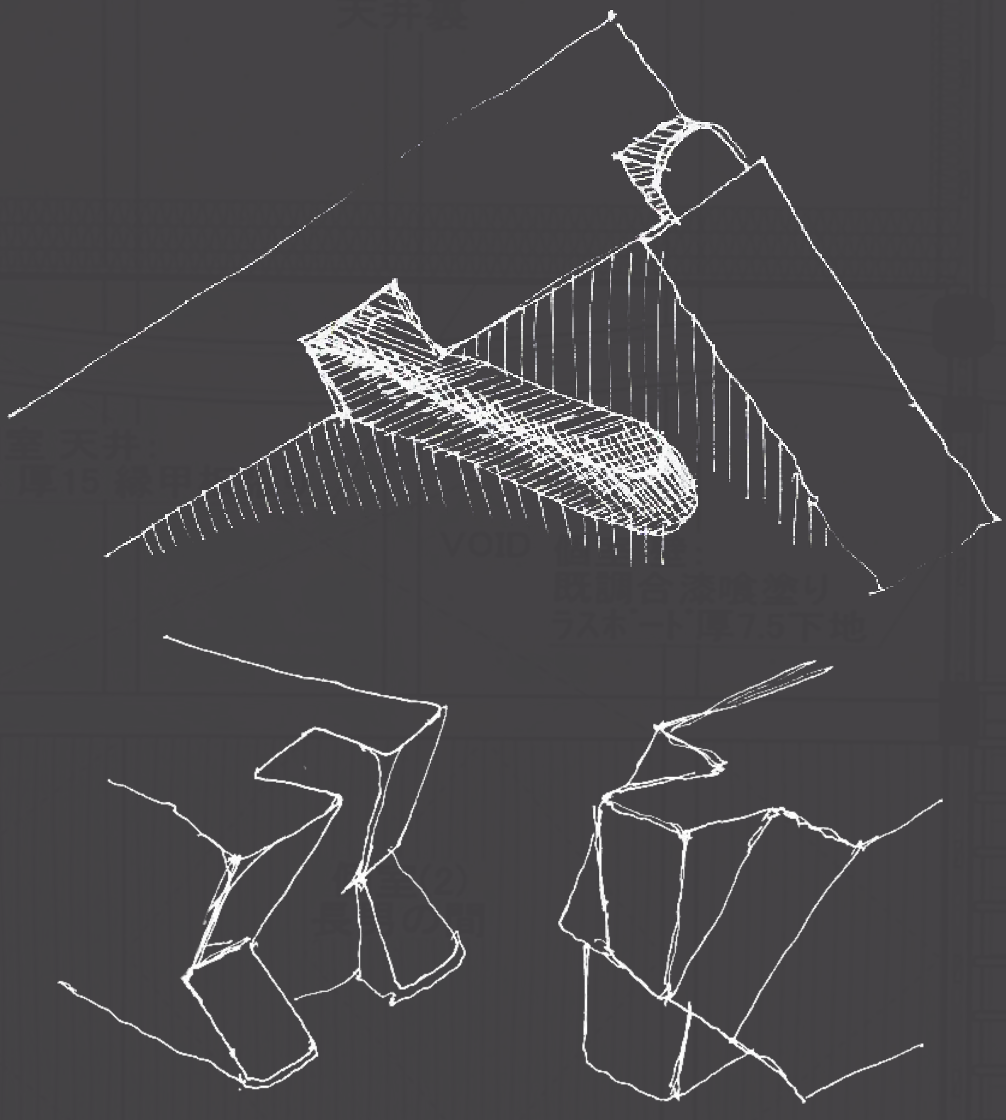
There is a call for more house building in the UK to tackle housing shortages and housing affordability. If we invest in learning about progressive approaches and achieving high-performance homes, we may not need to re-build these homes for many decades to come.



Student-built cabin
Yestermorrow Design & Build School
Vermont, USA

Japan and New England

There are many countries well known for their approach to low energy housing and off-site construction. These include Sweden, Switzerland and Germany. Many products from these countries are currently imported to the UK, and there have been many visits by UK delegations to learn from them. The following pages outline the reasons for travelling to central Japan and New England.



Timber joints
USA (above)
Japan (below)

Why Japan?

Off-Site

The housing industry in Japan is known to have one the world's highest proportion of prefabricated house building, widely reported to be high-tech, and operated using 'lean' management techniques borrowed directly from parent manufacturing companies. In addition to this reputation, Japan constructs a high number of houses each year, in part due to the fact that Japanese homes have a short lifespan of around 30 years. The reasons for this renewal rate are complex, with both economic and cultural factors at play. In 2017 the number of housing starts in Japan was reported to be 964,041. By way of comparison, the UK, the population of which is approximately half of Japan, achieves around 200,000 annually [UK Government 2017].

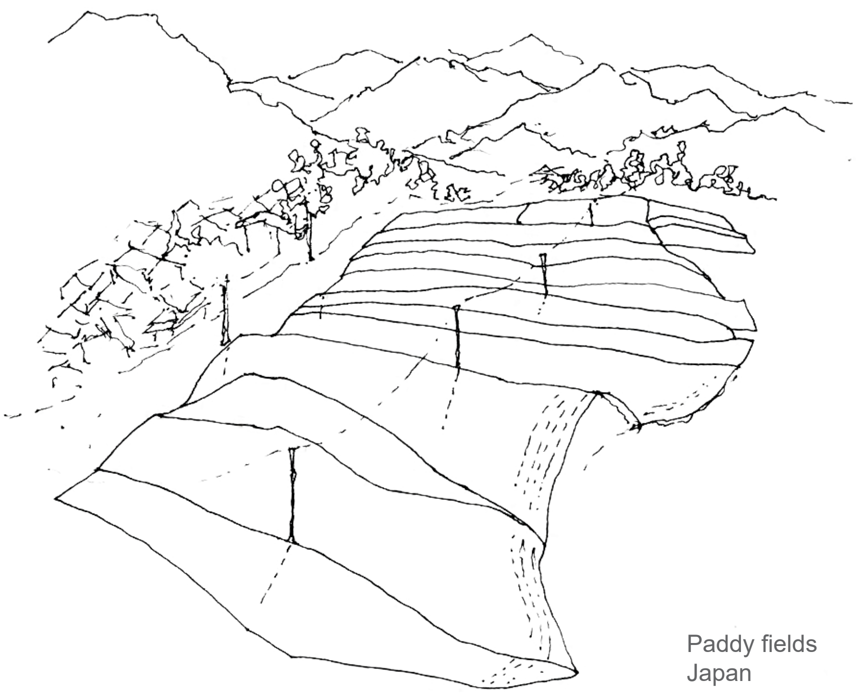
Timber

Traditionally Japan is known for its use of timber in house building, particularly in low-rise detached properties. Although it proved difficult to obtain recent data, in 1999 it was recorded that 56.6% of house starts were of 'wooden-based construction', which comprises 'traditional' post and beam, balloon-framed '2 by 4' and 'prefabricated'. (Iwai, 204). Of the 'wooden-based' house building it was estimated that 15% of these were prefabricated. Other sources report figures of between 13-18% of house starts being prefabricated.

Energy Efficiency

The Japanese government aims to achieve Net Zero Energy Housing (ZEH) design in all new homes by 2020. ZEH offsets energy consumption with energy generated by photovoltaic systems and other home-integrated renewable energy systems [Misawa Homes Annual Report, 2017, 5].

Japan has a reputation for high-tech solutions, and is reputed to be a world leader in off-site construction. It was hoped that lessons could be learned from their approach to performance and build quality.



Paddy fields
Japan

Why New England?

Off-site

I was aware of several companies operating in the off-site sector, in a similar way to some Scottish timber-frame companies. I was keen to visit them and draw comparisons with our approach in the UK.

Timber

It is well known that timber is a popular and familiar construction material in North America, largely due to its abundance and availability. Aside from timber framing and finishes, I was aware of moves to bring other timber products into the construction process, including wood fibre insulation boards and blown wood fibre insulation.

Energy Efficiency

As well as a growing use of the Passive House standard, the USA is known for engaging with environmental standards such as *Leadership in Energy and Environmental Design* (LEED), and more recently the *Living Building Challenge*.

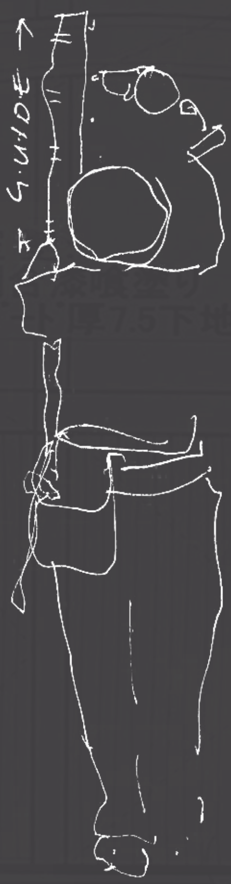
The types of issues being tackled by the environmental movement in the US are very similar to our own concerns in the UK. For example LEED certification is achieved by gaining credit points through both mandatory and optional criteria. The credit points are structured to achieve Silver, Gold or Platinum levels, and the criteria are based on the following:

- Location & transportation (including access to transport, bicycle facilities)
- Sustainable sites (protecting habitat, rainwater management, heat islands and light pollution reduction)
- Water efficiency (indoor and outdoor water use reduction)
- Energy and atmosphere (energy performance improvement on baseline requirements, energy metering, renewable energy production)
- Materials and resources (Recycling, waste management, sourcing of raw materials, life-cycle impact reduction)
- Indoor environmental quality (Indoor air quality, low emitting materials, thermal comfort, interior lighting, daylighting).

I was confident in finding like-minded practitioners and companies tackling the issues such as energy efficiency and building performance.

Methodology

My Fellowship was undertaken during summer 2018, and my time was split between Japan and New England. I had identified a number of companies, organisations and specific projects that I wanted to learn more about.



Finishing a ‘module’ at the Sekisui House factory
Japan

Japan

I was aware that the corporate culture of Japan can be very closed to outsiders, and as such I planned to join a tour organised by my former university tutor, Dr Masa Noguchi. The annual tour, which is run as part of the Zero Energy Mass Custom House network (ZEMCH), visits several major Japanese house builders. I spent the second half of the trip visiting other contacts in the building and architectural fields. In particular I was much welcomed by the founder of Passive House Japan, an architect called Miwa Mori, and several of her contacts in the construction industry.

Of the major house Japanese companies, the ZEMCH tour visited Misawa Homes, Sekisui House, Daiwa House and LIXIL. We visited a variety of factories, visitor centres, show home villages and research establishments.

My time with Passive House Japan representatives was a series of meetings and interviews, site visits and a seminar in Kyoto. I was able to have technical conversations and to learn about specific materials, construction techniques and timescales.

I undertook several visits to ‘show home villages’, where one can visit show houses by several different house builders – from large companies to smaller local firms.

I had the opportunity to observe and photograph many of the building sites I found in my extensive walks around Tokyo, Kyoto, Nagano, Nikko and Kobe. One finds that there are numerous builds happening on gap sites within residential areas, often left unsecured and with tools and materials left out overnight.

New England

My initial contact with builders and architects in the USA was very positive. I arranged to visit several design and build companies, two architectural firms who also run design and build companies, and two significant social housing projects that have both achieved Passive House certification. Of the social housing projects I was also very keen to meet the developer clients, and to learn what had persuaded them to invest in a Passive House project.

I toured the factories of several timber-framed design and build companies. Typically, the companies were happy for me to ask probing questions and photograph their premises. We found a lot of common ground with my work back in the UK.

Having had such a positive experience with Passive House Japan, I attended a Passive House site visit and seminar in New York State. The attendees were generally architects working in the field of low energy building design. There was much discussion of the software available for designing and testing Passive Houses.

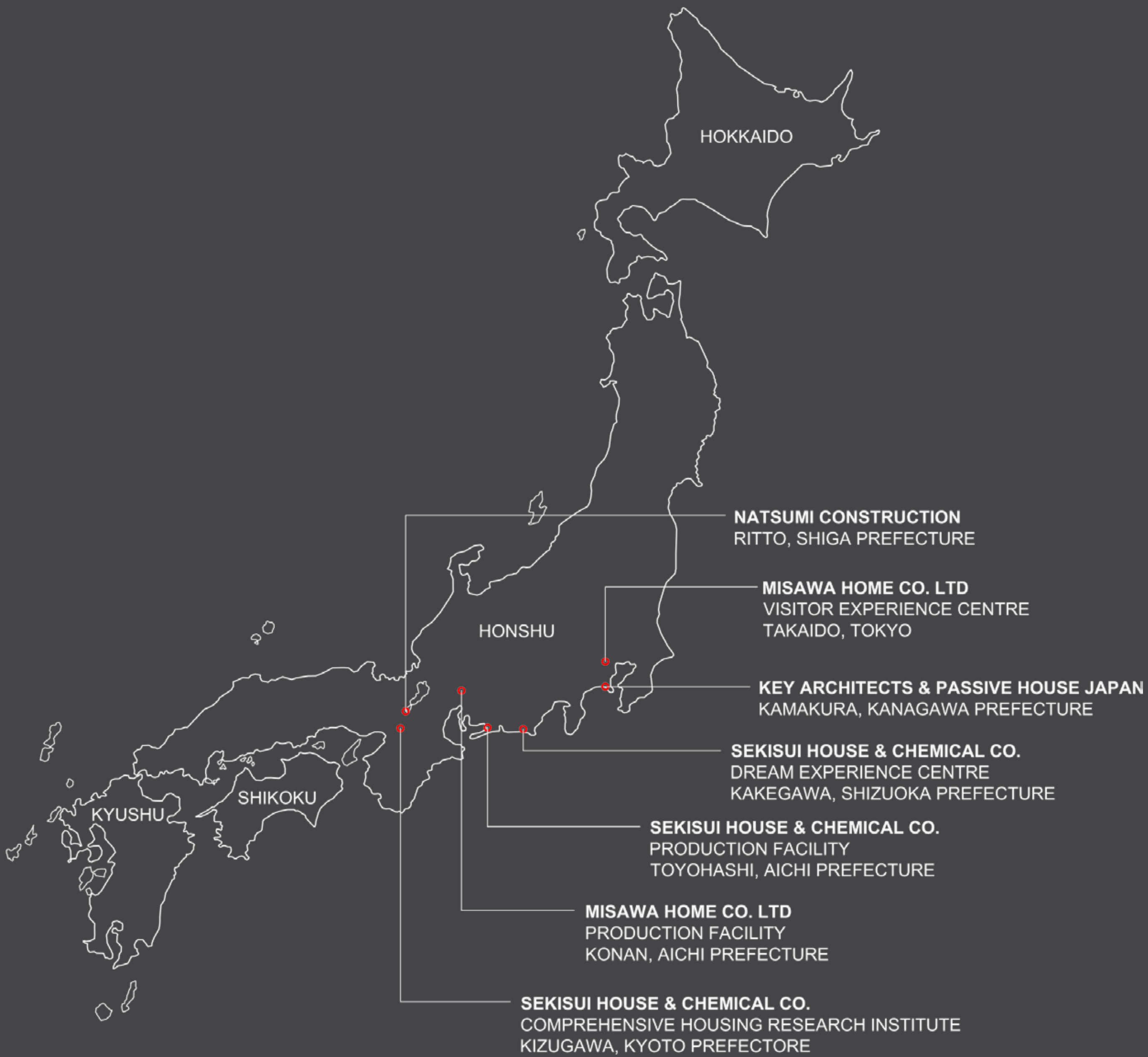
I had identified two specific projects in New England, which had delivered Passive House-certified multi-home housing. I was able to interview the architects for each project as well as the developer client for one of them. I also toured one of the developments, and was able to observe the other from outside.

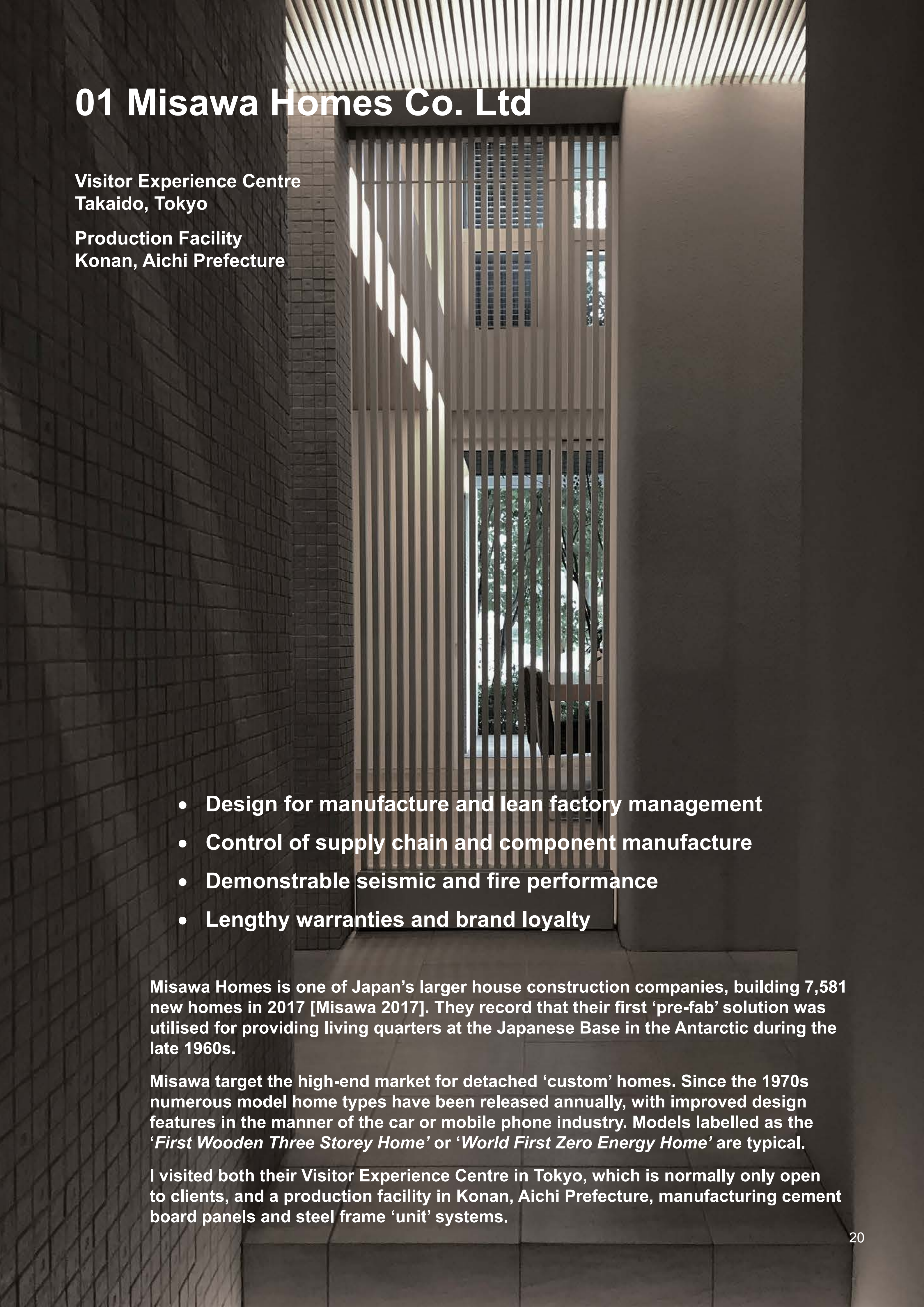
It was generally easy to speak to people that I met and stayed with about their views on housing delivery and housing performance. I was able to garner a lot of background information about the country I was travelling in, and I began to form thoughts around larger concepts such as rural employability, regeneration of manufacturing industries and assessing the potential for locally available materials.

Unless otherwise specified all photographs and sketches in the report are the author’s own.

Case Studies | Japan

1. Misawa Homes
2. Sekisui House and Chemical Co.
3. Key Architects and Passive House Japan
4. Natsumi Construction





01 Misawa Homes Co. Ltd

Visitor Experience Centre
Takaido, Tokyo

Production Facility
Konan, Aichi Prefecture

- **Design for manufacture and lean factory management**
- **Control of supply chain and component manufacture**
- **Demonstrable seismic and fire performance**
- **Lengthy warranties and brand loyalty**

Misawa Homes is one of Japan's larger house construction companies, building 7,581 new homes in 2017 [Misawa 2017]. They record that their first 'pre-fab' solution was utilised for providing living quarters at the Japanese Base in the Antarctic during the late 1960s.

Misawa target the high-end market for detached 'custom' homes. Since the 1970s numerous model home types have been released annually, with improved design features in the manner of the car or mobile phone industry. Models labelled as the '*First Wooden Three Storey Home*' or '*World First Zero Energy Home*' are typical.

I visited both their Visitor Experience Centre in Tokyo, which is normally only open to clients, and a production facility in Konan, Aichi Prefecture, manufacturing cement board panels and steel frame 'unit' systems.

'Unit' assembly line - Extract from Misawa Homes brochure 2018

Off-site

Misawa has seven factories across Japan, four of which produce timber-based panel systems, two that produce components such as kitchens, and the last is described as producing 'hybrid systems' which I visited during the ZEMCH tour. This particular factory manufactures 247 homes per year, and employs 248 people, including 70 staff in the design and engineering departments.

Misawa reported that the majority of the homes they build are timber panel systems, with a small proportion of steel modular buildings. They claim to be able to assemble the kit of a timber house within a working day on site. This sits within a total of 60 days on site, including the preparation of the ground and foundations, and finishing the kit internally and externally. The lead-in time to book a slot in the factory was reported to be 2 months.

In the factory visited I saw the evidence of 'lean' management principles all over the factory, such as a visual 'Daily Plan' and graphs outlining the number of workers required per process. We were told that any workers involved with a shorter process can be 'borrowed' to help a colleague finish a longer process. A visual 'skill set' table allows supervisors to quickly re-assign workers based on their skills.

Photographs were prohibited in the factories, therefore I have relied on notes and sketches made during the tour as well as images from Misawa-produced literature.

'Panelised' house drawings

Materials

Currently Misawa systems are available as panels constructed of both timber and steel, as well as modular steel frames known as 'units'.

Although Japan is a very heavily forested nation, the majority of timber for construction is imported from overseas. This is in part due to high labour costs and mountainous terrain, which makes Japanese logging expensive. [Iwai 204].

Using foreign-grown timber makes the supply-chain more difficult to control, therefore in order to secure and control their supply chain, Misawa has owned and managed a Finnish forest since the 1990s, using a sister company called Misawa Homes of Finland Ltd. Timber

Extracts from Misawa Homes brochure 2018

Extract from Misawa Homes brochure 2018

Example of Misawa wall construction

for construction is produced in Misawa-owned sawmills in Finland, much of which is shipped back to Japan and used by the company.

The Konan factory produces steel-framed 'units', ten or eleven of which will be used to build an entire home, with each unit fitting the dimensions of a medium size lorry, and not exceeding 4 tonnes in weight. It was reported that it would take a construction team one working day to assemble all the 'units' for one house.

The units are clad in 80mm thick cement board cladding panels, produced by Misawa in an adjacent factory. Although the panels are available in a finite number of patterns and colours, each panel is bespoke manufactured for each house, and openings such as windows and doors are pre-cut. Standardised moulds for common components such as corner junctions are used, as are standard jointing details. We were told that this product combats the problem of an ageing and diminishing workforce as it relies far less on the manual labour required to produce a traditional tile 'effect' finish.

Misawa Seismic Design Experience Room
Visitor Experience Centre, Tokyo

Thermal performance

A model of a typical Misawa wall build-up showed a 95mm stud timber wall insulated with mineral wool. Although no performance information was available, I calculated that the U-value of such a wall would be approximately 0.35 W/m^{2}K. Currently the UK baseline standard for new homes is between 0.22 - 0.30 W/m^{2}K for walls and 0.18 W/m^{2}K for floors, with many new build achieving considerably better values. The Misawa sectional models also demonstrated some fundamental cold-bridging taking place at the junctions of floor, walls and roof.

The Japanese climate varies greatly from the UK, and therefore a direct comparison between national base-level thermal performance cannot be easily made (although the use of a Passive House PHPP calculation would give a useful indication). Two of the volume house builders visited on the ZEMCH tour do not build in the north of the main island of Honshu, or on the northern island of Hokkaido, being quite open about the fact that their buildings would not be suitable for colder climates.

Typical house construction, Misawa Visitor Experience Centre, Tokyo

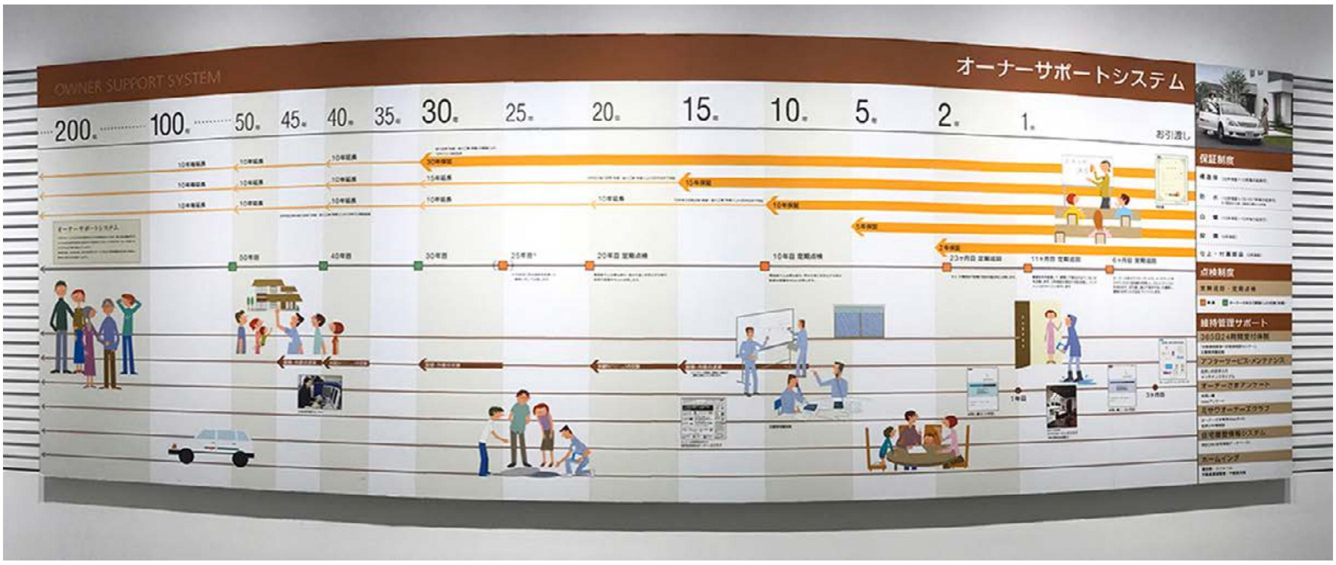
Pollen blower, Misawa Visitor Experience Centre, Tokyo

Energy Balance

In Misawa corporate literature the government-led Net Zero Energy Housing (ZEH) standard is referred to, which essentially offsets home energy use through integrated renewables and photovoltaics. Misawa aims to achieve this for all their homes before 2020.

The question of whether energy use can be reduced through improving the fabric of the building was not addressed during our tour, however the show areas dedicated to technology and equipment for saving energy are extensive, and their houses demonstrate a range of Passive measures for reducing energy use: Misawa show homes were cooled with radiant wall cooling systems rather than air-conditioning, and even featured garden fences that provided cooling through a dripped water evaporation system. Domestic equipment such as air-source heat pumps are displayed in show rooms with labels regarding efficiency and performance.

Some of the technology was very specific to Japanese culture, such as a 'pollen blower' located in the entrance porch to remove the allergy-inducing substance before one enters the home.



200 year chronology of 'Owner Support System', Visitor Experience Centre, Tokyo

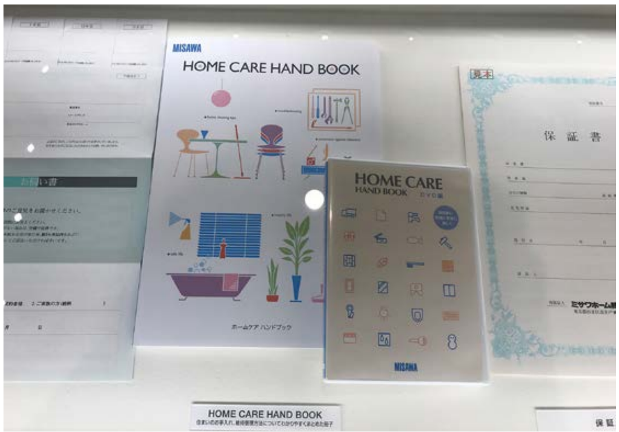
Earthquake proofing

Misawa excels in their extremely high-tech and in-depth testing and demonstration of seismic dampening options in order to reduce house shake during earthquakes. I was to learn that the majority of injuries and deaths due to earthquakes are caused by falling furniture rather than full house collapse. It is therefore of great importance to customers that their home shakes as little as possible.

The dampener systems were a hybrid of racking within the frame with specialised cross-bracing, and pad foundations with a tolerance for movement between the home and the pad. These systems are described as an 'optional upgrade', which we were told around 75% of customers choose to specify. The dampening systems are demonstrated in state-of-the art Experience Rooms, which include 'rides' in a simulator and scale models demonstrating the shake of a Misawa home compared to a traditional post and beam house.

Warranties

Another area in which Misawa excel is their approach to warranties, and their focus on customer loyalty to the brand. A graphic on the wall showed the '*Customer Support System'* over a two-hundred year period. Their typical warranty covers thirty years, which resounds with the cultural norm for replacing homes over this age.



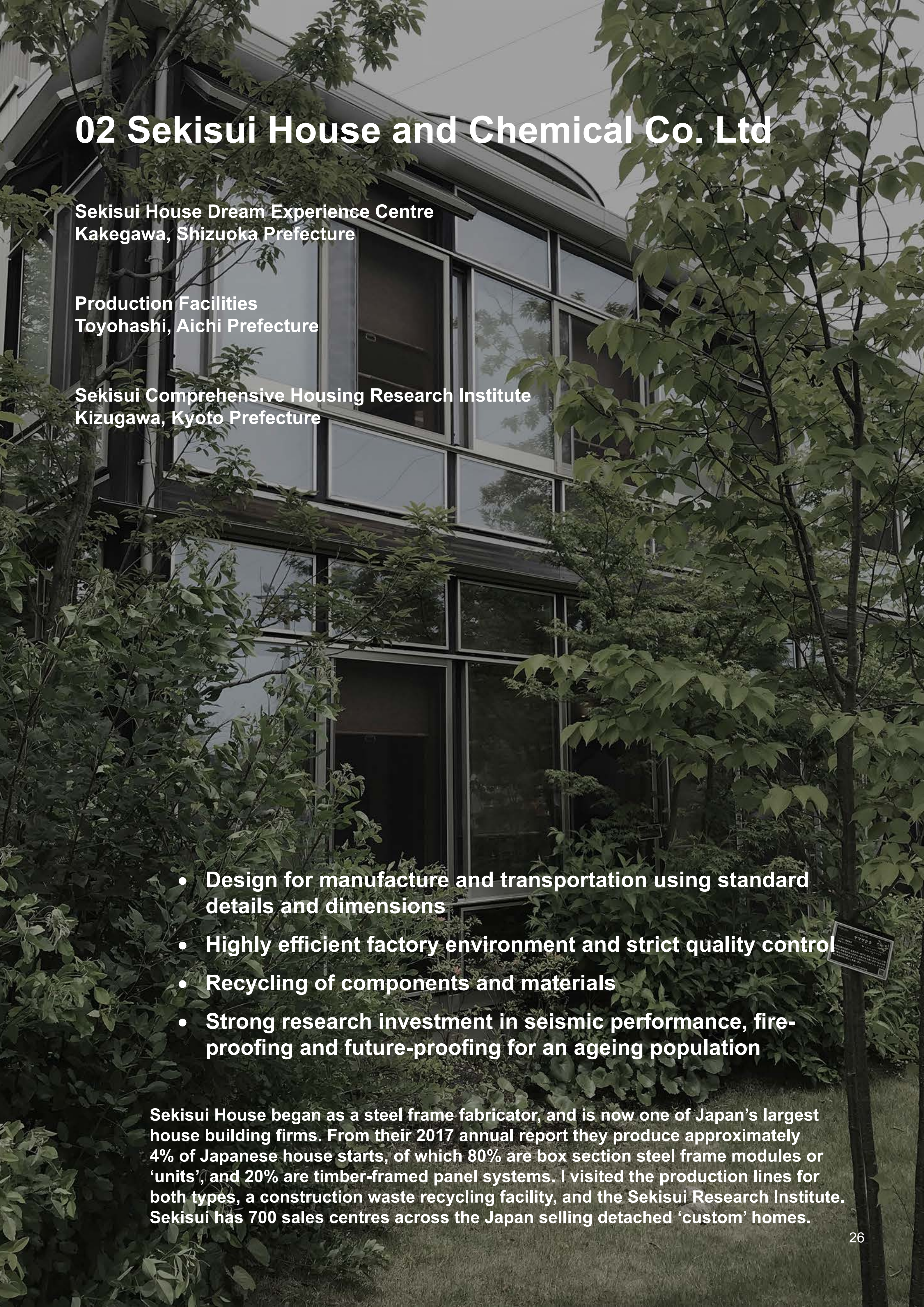
Misawa Home handbooks, Misawa Visitor Experience Centre, Tokyo

Conclusion

The Misawa factories I visited were well organised and demonstrated many aspects of 'lean' management. The production line appeared to be efficient and well organised, with well-established lead-in times, and a steady supply of work.

It was particularly interesting that Misawa take a great deal of control over their supply chain and material sourcing. It was apparent that they had thought through their material-use very carefully, and had invested in production facilities for specific components, such as the cement cladding panels.

Although energy performance was not as impressive as anticipated, there is a strong awareness of energy balance regarding use and generation, and a great deal of research into other areas of performance and maintenance.



02 Sekisui House and Chemical Co. Ltd

Sekisui House Dream Experience Centre
Kakegawa, Shizuoka Prefecture

Production Facilities
Toyohashi, Aichi Prefecture

Sekisui Comprehensive Housing Research Institute
Kizugawa, Kyoto Prefecture

- **Design for manufacture and transportation using standard details and dimensions**
- **Highly efficient factory environment and strict quality control**
- **Recycling of components and materials**
- **Strong research investment in seismic performance, fire-proofing and future-proofing for an ageing population**

Sekisui House began as a steel frame fabricator, and is now one of Japan's largest house building firms. From their 2017 annual report they produce approximately 4% of Japanese house starts, of which 80% are box section steel frame modules or 'units', and 20% are timber-framed panel systems. I visited the production lines for both types, a construction waste recycling facility, and the Sekisui Research Institute. Sekisui has 700 sales centres across the Japan selling detached 'custom' homes.

Off-Site

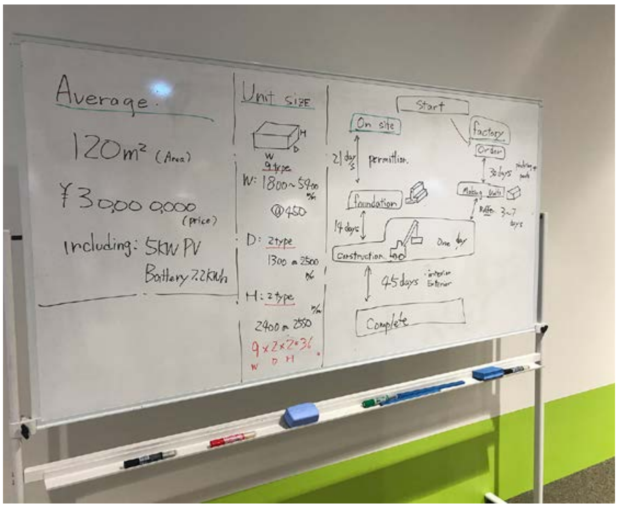
With the ZEMCH tour I visited the Sekisui steel-frame factory in Aichi prefecture, and the adjacent timber panel factory. The steel factory was built in the 1980s for 80 million Yen (around £500,000 at the time), and currently produces 20 houses per day. Three-dimensional 'units' are produced to form a variety of customised designs, which is dictated within the software used to design the homes. The diagram below gives an overview of the production process.

A great effort is made to keep modules moving rapidly through the factory: Double height working platforms allow two teams to work concurrently on the 'unit', on both the ceiling/roof area, and below on the walls and floor. More than one team member will be working at the same time, and in turn the unit moves on to the next stage fairly rapidly. The effect is that of an automotive production line, with each stage heralded by keyboard jingles over loud speakers. The efficiency is apparent, with one unit taking six hours to pass through the production line including internal lining and wiring for electrics and lights

An effort is made by Sekisui to connect the factory workers with the end-customer: At the entrance to the factory a large display cabinet displays the photos and details of current customers.

The factory tour highlighted Sekisui's detailed approach to off-site manufacture: The units are dimensioned to the maximum size allowed for road transportation – 2.50m wide by 2.55m high by up to 5.40m long. It was explained that the specialist software used by the designers restricts the 'custom' designs to fit these dimensions, and that standardised components are chosen from a library.

Customer information board, Sekisui Factory



Sekisui House 'Key Facts' board

In order that the site assembly runs smoothly the unit dimensions are checked with lasers in the factory. Ensuring exact dimensions prior to assembly allows for the connections on site to be planned in advance, without modification required during the on-site assembly.

As well as planning ahead for site assembly, there is an emphasis on quality control and ensuring defect-free units leave the factory ready for site. An introductory film explained that female inspectors with '*an eye for detail*' are employed to ensure quality control at the end of the production line. The benefit of spending time ensuring quality in the factory is that snags and defective work are caught whilst they are still accessible, and before the module is transported to site.

The adjacent factory produces timber-framed panels, also for detached-custom homes. The factory bore similarities to a UK framing workshop, with lanes for framing and sheeting. The factory also had equipment that is quite common in the larger UK off-site companies, such as automated nailing machines.

Members of the ZEMCH group were somewhat startled at how 'low-tech' parts of the factory appeared, with joiners bent low over panels at floor height, nailing and screwing the frames together. I have since learnt that Japanese carpenters traditionally work on the ground and use tables far less than their Western counterparts.

Although the timber-frame factory appeared to place less emphasis on final quality control checks, information boards situated at work stations give information on standard details and quality, so as to ensure everyone has the information to work to the same standard.

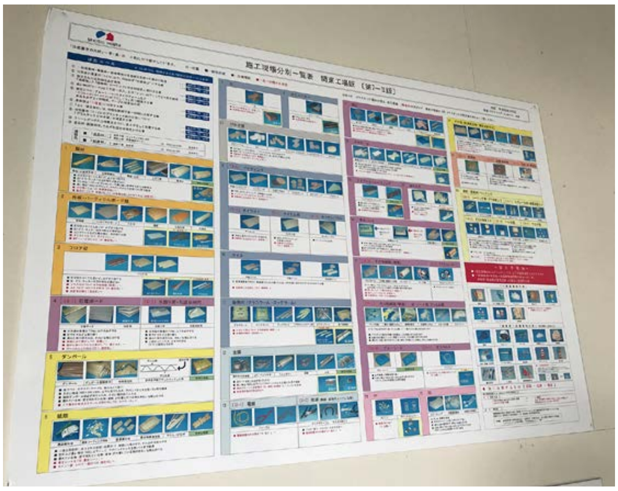
Recycling centre

Adjacent to the two factories is a large steel portal-frame building, where it is claimed that 100% of site and factory construction waste is recycled.

Sekisui estimate that there are approximately 160,000 individual components in a typical house, and they divide the materials into 27 categories for recycling.

Employees work in lines sorting materials and components including off-cuts of insulation, plasterboard, plastics and wiring, all brought back from site in lorries. We witnessed a rapid 'deconstruction' of a tatami mat by one worker, with the component parts separated in under a few minutes. The Sekisui tour guide explained that they have been working with their suppliers to adjust the design of some components in order to make them easier to deconstruct and recycle.

Materials for recycling being sorted



Sekisui recycled materials information board

Materials

The majority (around 80%) of Sekisui detached homes are built using box-section steel-frame modules, and the remaining 20% are built using timber-framed panels, which are similar to timber systems found in the UK.

Despite a cultural preference for timber 'traditional' type homes, Sekisui is obviously very successful in selling their steel-frame homes. To some extent, this may be due to the large investment in their factories and automated equipment, which in turn incentivises Sekisui to heavily market the advantages of steel as the primary material. Seismic protection in particular uses steel systems.

The other reason for the success of steel frame may be even simpler, that the Sekisui homes are not readily apparent as being made from a particular material, and do not look 'prefabricated'. The Sekisui show homes we visited were 'luxury' homes, with high-end finishes and furnishings. The interiors did not appear to be modular or standardised, in fact the houses were full of interesting, sometimes quirky, light-filled spaces.

The Sekisui marketing appeals to high-end customers, there is an emphasis on factors such as low-maintenance and luxury materials for the finishes and appearance. Cladding is generally fire-proof cement boards, and external spaces are finished with 'low maintenance' materials such as timber-effect plastic decking. The interiors are lined with plasterboard, timber, tile, and stone-effect 'feature walls'. The actual construction and performance of the building fabric is emphasised less, and this may reflect what their customers are interested in.

Full-size seismic testing
Image taken from Sekisui literature

Performance

The performance of Sekisui homes plays a major part in their marketing. At the Kyoto Research Institute and Experience Centre, a wide range of interlinked themes are presented, including comfort and lifestyle, fire proofing, seismic protection and improved energy efficiency.

Fire-proofing and seismic protection feature heavily in marketing material and in the customer visitor centres. Non-combustible cladding is demonstrated in the lab with a live demonstration using a flame thrower. Seismic protection is demonstrated through two full-size dining room simulators, each demonstrating a different level of seismic protection. As we saw at Misawa Homes, the seismic protection is available at a standard level, and as an improved optional 'upgrade'.

At the Kyoto Research Institute, testing is taken a step further with a triple-height hall used to test full size house models. The models undergo many tests including seismic weather-proofing and wind loading.

Sekisui demonstrate an awareness of an ageing customer base, with an entire department dedicated to home equipment and furnishings designed for use by those who are disabled or impaired. A library of outfits and props allow customers to 'experience' the difficulty of operating their home with conditions such as arthritis, broken limbs or cataracts.

Full size testing - Extract from Sekisui literature

Holistic approach to house building : Sekisui veg garden

The Sekisui approach to energy efficiency was less thorough, although by no means ignored. Improved energy efficiency is demonstrated with experience rooms that are chilled to demonstrate the improvement in thermal comfort between single and double glazing.

Sectional models of wall build-ups and windows are presented alongside information about improved thermal conductivity values. There is also information presented about the Sekisui Zero Energy Home model (ZEH), which uses four times the amount of insulation as was typically used during the 1990s.

The improved U-values do not meet the baseline standards for the UK, with a wall sitting at 0.647W/m^{2}K and a floor at 0.359W/m^{2}K. As discussed in the Misawa Homes case study, the current UK baseline standards are considerably higher than this. I cannot easily compare the UK climate and home energy requirements with those of Japan, but this perhaps demonstrates that energy efficiency is not the main thrust of Sekisui's marketing strategy, or a key factor for the majority of their customers.

Conclusion

The Sekisui Research Institute demonstrates the extensive time and money the company invests in product and process development. Although my key interest of energy efficient-fabric appeared to be a less important factor, it was impressive to see the enormous effort undertaken in the areas of performance that Sekisui values most highly.

03 Key Architects and Passive House Japan

Kamakura, Kanagawa Prefecture

- **Single and multi-home Passive House developments**
- **Bringing experience from abroad back to Japan and applying it appropriately**
- **Seminars and lectures to disseminate Passive House education to architects, contractors and clients**
- **Working with foreign and domestic manufacturers to establish component manufacture within Japan that meets Passive House criteria**

I was fortunate to make the acquaintance of architect Miwa Mori, director of Key Architects and founder of Passive House Japan, based in Kamakura, Kanagawa Prefecture. Ms Mori welcomed me to a Passive House seminar she was hosting in partnership with Natsumi Construction, based in Ritto, Shiga Prefecture. She also invited me to the offices of Key Architects to learn about some of the projects they have undertaken, particularly in the field of Passive House.

The work of both organisations displays an impressive effort to introduce Passive-level standards to house construction in Japan. There is an engagement with important issues such as construction processes and supply chains, as well as design approaches.

Off-site

In general Key Architect-designed houses are framed on site using pre-cut, pre-jointed timber, with the shell completed on site. The focus of Key Architects is that of performance, and as such we did not particularly discuss the construction process, other than the challenge of achieving Passive-House detailing, and ensuring that high quality workmanship is maintained throughout the build.

Key Architects promotes the use of smaller local builders, such as Natsumi Construction, who are engaged with issues such as thermal performance and high-quality construction. There was a frustration that many of the larger off-site house building companies promote a 'luxury' image, but fail to produce high-performance buildings.

Example wall constructions at Passive House Japan seminar

Foundation detail seen during a Passive House Japan tour

Materials

Key Architect-designed homes are typically built using a pre-cut timber frame, which is insulated between the studs and outside the frame. The exact choice of materials and specification varies between projects, with cost and performance being weighed against each other.

Cedar is generally used for framing, and there is a preference from clients for Japanese-grown timber, although this is a more expensive option compared to imported timber. Cypress is valued for its aroma, and is sometimes used for internal linings, particularly in bathrooms.

Insulation varies between projects, including glass-wool, cellulose, wood fibre board and phenolic-foam insulation board. Wall depth ranges from 230mm to 360mm, depending on the required U-value. Miwa Mori noted that both blown wood fibre insulation and cellulose insulation are manufactured in Japan.

Roofs are covered with lightweight tiles or sheet metal. Ms Mori explained that the traditional heavy tiles seen on older Japanese homes have become less common as cheaper, lighter alternatives are offered on the market. Although using the lighter material reduces the overall building weight, helping to meet the criteria for earthquake regulations, the lighter sheets are more vulnerable to damage from high winds.

Performance

As a leader of the Passive House standard in Asia, Key Architects take performance and energy-efficiency very seriously indeed. Miwa Mori previously worked in both Germany and Ireland before establishing Key Architects, and brought back her experience of Passive House to Japan.

Passive House is relatively new to Japan, and there are very few certified buildings in the country. In order to promote the standard, PHJ hold regular seminars and conferences. The seminar I attended included a tour of a renovated home to near-Passive standards, a new build home also constructed to near-Passive standards, and a variety of lectures covering topics such as shading modelling, specialist glass products, and a publication about thermal bridging.

Model of Key Architects-designed home

PHJ has worked on a variety of projects to make Passive House design more accessible to Japanese architects and builders. Initially the software for Passive House design was not available in Japanese, and the PHJ members have participated in translating the software and manuals. Alongside this, work has been done in developing a Japanese-language CAD-friendly plug-in for inputting data to the modelling tool PHPP. By making the Passive House tools more accessible it is more likely that they will be used.

Example of timber-frame house building seen in Nikko

PHJ have also tackled the challenge of the specialist components required for certified Passive Houses being available only from abroad, typically northern Europe. This particularly applies to windows and doors. Miwa Mori has worked with Japanese manufacturers in order to develop products, or to partner with existing Passive House component manufacturers abroad to make these components more readily available in Japan. During the seminar I attended there was a number of sample windows from German manufacturers on display at the construction site.

Conclusion

Key Architects and Passive-House Japan are collectively promoting an approach which is not yet mainstream in Japan. Through experience gathered by working and travelling abroad they are applying the principles of energy-efficient design to the Japanese context. Miwa Mori in particular has applied her expertise towards not only design, but to construction processes and supply-chains, all of which are hugely important in the delivery of cost-effective high-performance buildings.

04 Natsumi Construction

Ritto, Shiga Prefecture

- **Off-site manufactured timber frames for rapid assembly on site**
- **Upgrading of typical construction assemblies to meet Passive-house performance levels**
- **Use of local timber and materials combined with high-quality carpentry techniques**
- **Engagement with other local firms to share learning of new techniques and share marketing costs**

Natsumi Construction is a small family construction company based in Ritto on the outskirts of Kyoto. The company is typical of many smaller Japanese builders in that they typically construct single family homes for private clients. They are also involved in refurbishment work including the use of traditional carpentry. The company are committed to improving the energy efficiency of their projects, and CEO Satoshi Natsumi is the Chief Software Trainer for Passive House Japan.

I visited three projects undertaken by the Natsumi company: These were a recently finished new-build house, and an older house that had been extended and upgraded to Passive House standards. Later in my trip Mr Natsumi invited me to visit an ancient pharmacy building in the town of Nagahama, Shiga Prefecture, where his firm was undertaking painstaking restoration and refurbishment in collaboration with the Tokyo architect Mr Ikuo Matsui.

Construction

Natsumi Construction do not particularly employ off-site methods in their construction process, rather they used a modernised version of traditional framing.

Like many smaller Japanese builders, Natsumi use pre-cut timber frames as the superstructure of the houses. The assembly of the frame takes approximately one week on site. Mr Natsumi estimated that a house could then be made wind and water-tight over a period of three weeks, with internal fit-out taking a further 3-4 months.

Throughout my time in Japan I would frequently come across timber-framed houses under construction on gap sites in residential areas. The fact the sites were left open is perhaps testament to the trusting nature I found all over Japan.

Foundation detail at a Natsumi construction site

Interior of a Natsumi house-refurbishment to near-Passive level

Window detail by Natsumi Construction

Materials

Although the material specification can vary between projects, the Natsumi new-build house I visited was typical of a number of their projects with the construction system summarised below.

The foundations are constructed from in-situ poured reinforced concrete strips, with a metal sole plate to prevent termite infestation. The floor is constructed of timber joists spanning between the strip founds, creating a floor space void underneath, which requires adequate ventilation to prevent excess humidity.

The main frame of the house is made of Japanese-grown cedar sections at a depth of 95mm. The frame is insulated using glass-wool, and sheathed using a timber-based board. The sheathing is taped externally at all joints for air-tightness. The frame is then externally wrapped with 100mm high-performance phenolic-foam insulation board. The continuous insulation envelope combats the thermal bridging that would typically take place through the timber of the structural frame.

Timber framing for the cladding system is installed on the external insulation board, and fixed back through to the main timber frame using long dual-threaded screws. The buildings are clad with cedar shingles or render board. Internally the house is lined with plasterboard.

The roof is also framed in timber, and insulated within the frame. The insulation is cellulose fibre, which is manufactured on the north island of Hokkaido, is installed at a depth of 300mm. The roof covering is sheet steel, and internally it is sheeted with double plasterboard with a service-zone for pipes and wiring.

Performance

As one would expect from their association with Passive House Japan, Natsumi Construction take energy performance very seriously and have adjusted their standard construction system to improve thermal performance and air-tightness.

The wall system is improved by installing an additional layer of insulation externally onto the already-insulated frame. Natsumi Construction have various models of walls at their offices demonstrating the type of insulation they use and to what depths.

This has the effect of improving the U-value, hence reducing thermal losses through the building envelope. The advantage of this process is that the normal build can continue in a very similar way to a traditional build with only the added process of installing the external insulation. This is a less disruptive way to improve the building performance than by changing the construction system entirely.

Mr Natsumi is also the software coordinator for Passive House Japan, including a CAD programme linked to the Passive House Planning Package (PHPP). By linking the 3D models to the energy model different designs can be evaluated by PH designers, without the lengthy re-calculation typically required for PHPP analysis.

Air handling equipment in the attic of a Natsumi-built home

A local building firm feature in a magazine

Mr Natsumi and colleagues discuss construction techniques

An impressive aspect of Mr Natsumi's business was his frequent meetings with other local builders in order to learn from each other and share ideas. I attended an evening meeting with four other owners of local building firms in which they discussed a range of topics including construction U-value and air-tightness targets, market research, marketing strategies, and finally a beer and some food. The atmosphere was one of support and friendliness between local firms.

Conclusion

Natsumi Construction demonstrate the flexibility and willingness of a small firm to make changes and pursue higher standards. Their construction system is an improved version of traditional framing, and as such makes higher performance buildings easier to achieve. They don't particularly engage in off-site construction, although their process is a modernised, improved version of traditional frame construction. Their engagement with architects and other builders demonstrates the success that can be achieved through collaboration and shared learning.

Key Findings from Japan

During my time in Japan I experienced two approaches to housing provision, different in both scale and motivations. The first, that of the volume builders who offer a 'mass market customised' product, heavily marketed and optimised for off-site construction. The second, a modernised version of the small local builder and architect, striving to provide better performance houses suited to the Japanese climate.

Across all the case studies, there was a great awareness of the supply chain, and actions had been undertaken to control and influence it. This included companies owning and managing their own forest, developing relationships with component suppliers to improve recyclability, and working with foreign manufacturers to set up local manufacturing.

The houses going through the larger off-site factories were clearly designed for manufacture, with components delivered 'just in time' and modules moving seamlessly through the production line.

Although I did not find that the volume builders were as concerned with energy performance as I had anticipated, there were other areas in which they excelled in research and development, namely seismic and fire protection. The extensive research facilities I saw demonstrated that if the motivation were present, the Japanese companies could very effectively tackle the challenge of improving the thermal performance and air-tightness of their homes.

The smaller builders and Passive House architects I met were motivated to improve energy-efficiency and thermal performance. Their construction processes were less efficient in terms of initial site time, but the resulting buildings were of high quality and performance.

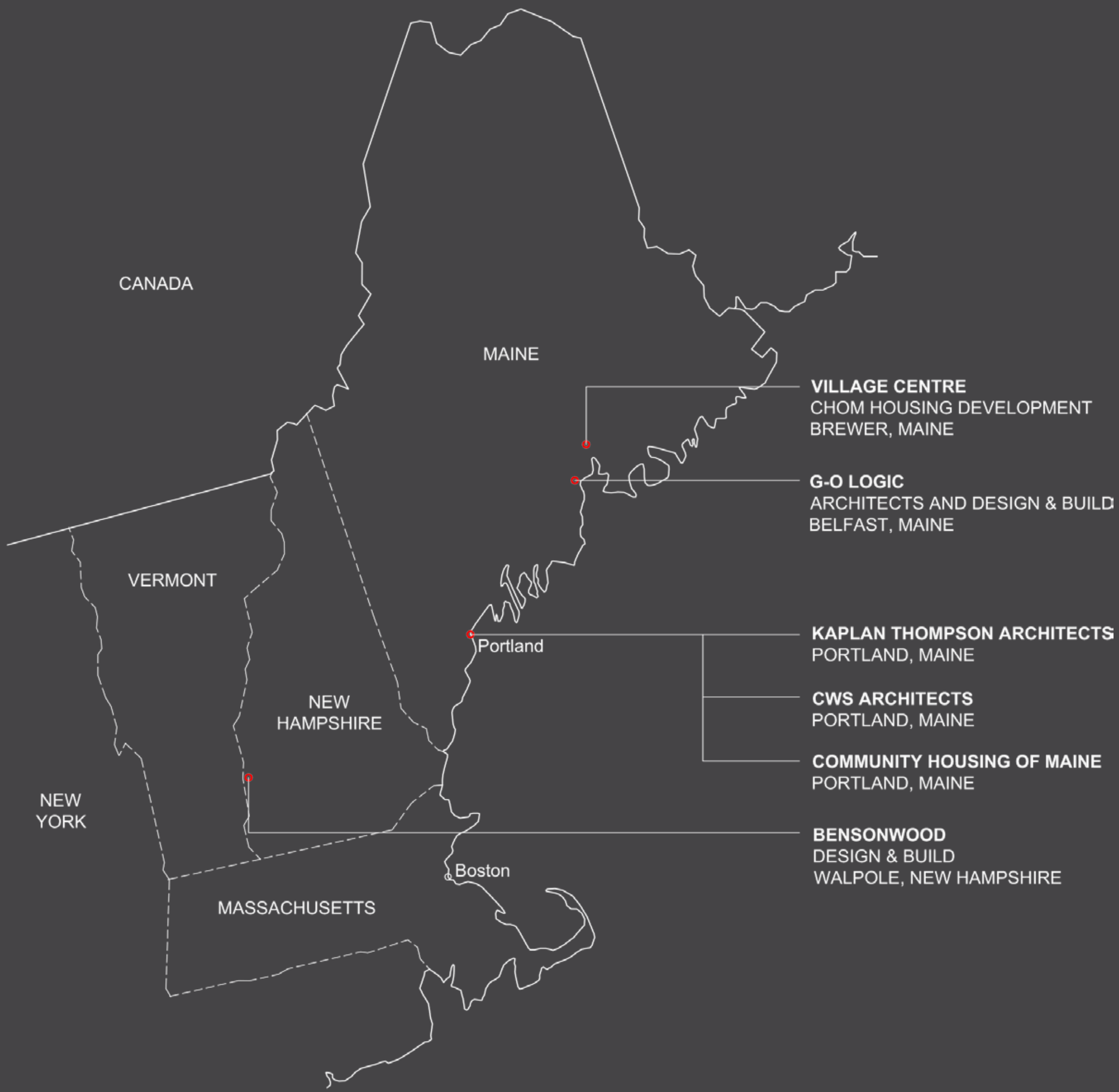
An impressive feature of the smaller companies was the level of interaction between builders and architects. Passive House Japan brings together a range of interested parties for support and education. Furthermore I saw competing building firms supporting one another on a wide range of topics including energy performance and how to make improvements.

My lasting impression of Japan was the energy with which the people were tackling the issues most important to them, and their willingness to work together to solve problems.

Houses
Japan

New England Case Studies

1. Village Centre – Passive House multi-family development
2. Bayside Anchor – Passive House multi-family development
3. G-O Logic – Design and Build
4. Bensonwood – Design and Build



01 Village Centre

Community Housing of Maine

CWS Architects

Brewer, Maine

- **Proving Passive House can be achieved within an affordable housing budget**
- **'Construction management' contract to encourage early designer-contractor collaboration and to allow design control throughout construction process**
- **Incentive for the developer through renewables pay-back**

The Village Centre housing development in Brewer, Maine was commissioned and is managed by Community Housing of Maine (CHOM) whose mission statement includes: '*To acquire, develop, own and maintain quality housing which is affordable for people with low-to-moderate incomes, including people who are homeless and/or have special needs*.'

The development is a three-storey building containing 48 one, two and three-bedroom affordable-rent apartments. The project was designed by CWS Architects based in Portland, Maine led by architect Ben Walter. The contractor for the project was Wright-Ryan Construction.

The apartments achieved US Passive House certification, and are rented out by CHOM to residents on low-to-moderate incomes. Space heating and hot water are included in the rental price.

I visited the apartments with CHOM Chief Operating Officer Kyra Walker, and we discussed the reasons for choosing the Passive House route for the project and how the building has been performing. I also discussed the design process with architect Ben Walter.

Off-site

Although off-site panel framing was used, there was no significant incentive to use off-site construction in this development. As with many Passive House projects, the key to the construction process was ensuring that a super air-tight envelope was achieved, which focuses on the careful jointing of components, which was done on site.

Importantly the contractual arrangement allowed for the architect to have a great deal of control during the construction process and detailing. The contract used for the project was called an AIA A133 CMC 2009 Standard Form of Agreement between the Client and the Construction Manager. This meant that the Construction Manager was brought on board early in the process, and could contribute during the detailed design stage. In turn this allowed for design control during construction to ensure that the meticulous detailing required for Passive House certification was adhered to. In order that costs were kept under control the majority of works were undertaken by sub-contractors, who had to individually bid for works packages.

Materials

Village Centre was constructed using an enhanced timber-frame, with double-stud ‘twin’ walls incorporating 300mm of cellulose insulation. A gap between the two timber frames allows there to be a continuous insulation layer. The architect Ben Walter explained to me that the approach to the construction process was about modifying what sub-contractors are used to, rather than changing everything at once.

Village Centre, Brewer, Maine

Performance

The building was not initially designed to be a Passive House, and Ben Walter has previously observed: *“Because we started with a building that wasn’t oriented and laid out to be optimal in terms of performance, this project demonstrated to us that anyone can build to passive house standards’.*

Computer modelling was used by the Maine-based energy consultant Thornton Tomasseti in order to ensure the building complied with US Passive House criteria. A number of variations were modelled varying the wall type, insulation, mechanical systems. These options were assessed against the tight budget. A 3D modelling programme called WUFI allows designers to quickly assess design changes against the PH criteria. Traditionally the inputting of data into the PHPP spreadsheet can be quite time-consuming, and can limit variation modelling.

The typical cost-increase one would expect for a Passive House project was tackled in a number of ways including a saving made from not requiring to install a full heating system, and an ongoing return to the developer from a roof-installed photovoltaic array. Multi-house buildings sharing party-walls do not typically experience as much heat loss as detached houses, therefore they do not typically require such enhanced wall and roof U-values. Kyra Walker reported that the construction costs were approximately 3% higher than typically expected for a multi-family development. However, the project costs were kept low enough, at $145 per sq foot, to qualify for Maine Affordable Housing Tax Credits.

The hot water storage for all of Village Centre

The building had been in use for less than one year when I visited, therefore CHOM did not yet have any in-use analysis available. However, the energy use is expected to be 60% less than a typical building of its size. This saving allows CHOM to charge lower rent to its tenants, with space heating and domestic hot water included in the rate.

There is an additional metered charge if the tenants use their air-conditioning system. The reasoning behind this was that a Passive House should only be at risk of overheating for a maximum 10% of the year. In reality, peoples’ opinion of a comfortable internal temperature varies greatly; I visited during a spell of particularly hot weather and quite a few tenants had reported using the air-conditioning that summer.

A large photovoltaic (PV) array installed on the roof of the building reduces the electricity usage of the building, therefore saving money for the landlord, CHOM.

Conclusion

The Village Centre project clearly demonstrates that it is possible to apply Passive-House level criteria to affordable housing projects. Although the project did not particularly tackle construction process or material choice, it was managed in a way that was conscious of both performance and affordability. Ben Walter, the project architect, is quoted as saying *‘…Most sites are not going to have optimal orientation. So you want to prove it can be done under not-ideal orientations or conditions, and not be super-complicated.”* It was hugely inspiring to see that the project appears to be working well for both developer and tenants, and that it has been achieved within the budget for publicly-funded affordable housing.

02 Bayside Anchor

Avesta Housing | Portland Housing Authority

Kaplan Thompson Architects

Portland, Maine

- **Passive House certification achieved within an affordable housing budget**
- **Twin wall construction based on familiar timber framing, and using familiar insulation materials**
- **‘Construction management’ contract in order to allow early collaboration between the architect and contractor**
- **Has led the architect to a focus on ever more challenging sustainable building standards such as The Living Building Challenge**

Bayside Anchor is an affordable housing and service hub development in the Bayside area of Portland, Maine. The project was developed by Avesta Housing in partnership with the Portland Housing Authority. The project bears many parallels with the previous case study, Village Centre.

The project was designed by Kaplan-Thompson Architects, and constructed by Wright-Ryan Construction. The development achieved Passive House certification, and was built for $149 per sq ft. There are 45 one and two-bedroom units, with 36 of these categorised as affordable, and 9 available at the market rate.

I met with the lead architect Jesse Thompson to talk about the project, and Kaplan Thompsons’ approach to delivering truly sustainable buildings.

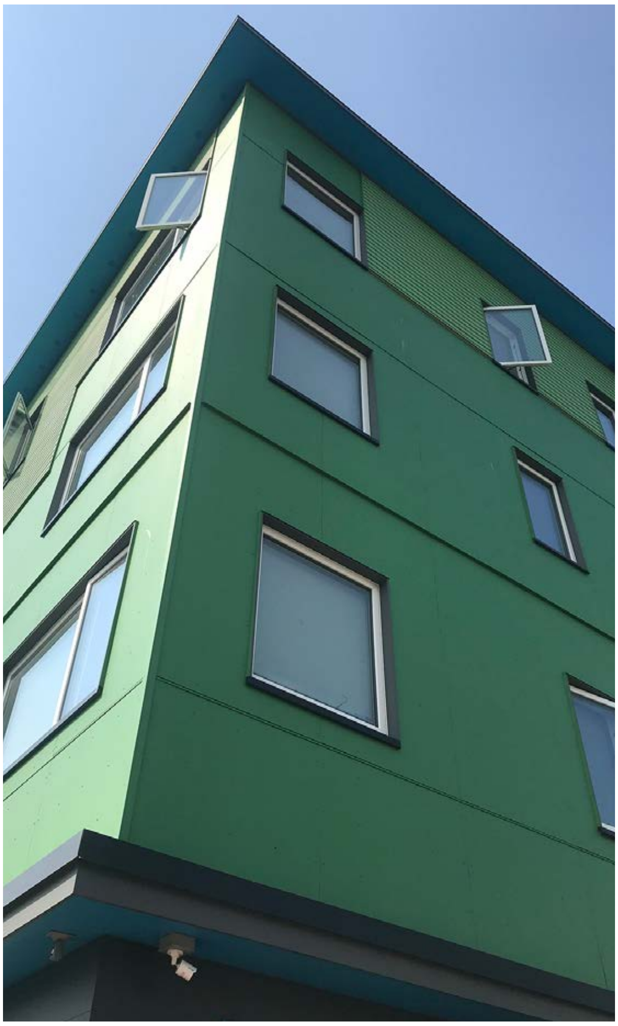
Off-site

The building was ‘platform’ built on-site with open frame panels erected to create the twin wall system described below.

Platform construction makes air-tightness difficult to achieve if the air-tight layer is on the inside face of the wall, however in this case the air-tight layer was fluid-applied to the external ply sheathing. It would have been difficult to apply the fluid layer onto off-site components unless there was a second site process ensuring an air-tight layer where the components come together on site.

This type of framing approach is commonplace in North America. Very little investment is required in order to produce the uninsulated frames, and it can happen in an off-site factory or adjacent to the building on site. Frames can be stacked and transported effectively. However, the building then requires substantial on-site work.

The Bayside Anchor development in context



Windows open during very hot weather in Maine

Materials

The materials used for the Bayside Anchor project are typical of North American construction: timber framing with dense pack cellulose insulation between the studs. Of the double stud frame, the external 145mm stud acts as the load bearing wall, and the internal 95mm stud has a lighter construction. A 25mm gap between the walls was also insulated with dense-pack cellulose, and creates a thermal break between the timber studs.

Jesse Thompson explained that pumped cellulose insulation is very common in the north of the United States. Local contractors are familiar using it, and it is manufactured in the USA. The main competitor to cellulose is spray foam insulation, which was perceived by all the architects I met to be a cheaper, lower quality, less ‘healthy’ material.

An excellent presentation regarding some of the detailing of the project can be found here.

Entrance to the Bayside Anchor development

Performance

Bayside Anchor achieved Passive-House certification, and is one of many progressive projects designed by the Portland-based architects Kaplan-Thompson. In a similar manner to Village Centre the building requires very little energy to operate, and additionally provides the owners with an income from roof-mounted photovoltaic panels.

In order to achieve the demanding Passive House standard a 'construction management' contract was used whereby contractors and sub-contractors are brought on board earlier in the process than a traditional procurement process. This allows for the valuable construction knowledge from contractors to be considered during the earlier design stages, which is vital to ensure that the building will achieve the Passive House criteria.

The building is fully mechanically ventilated, which is required for Passive House certification to ensure the internal air quality is maintained. Outgoing warm, stale air is passed through a heat exchanger where incoming fresh, cooler air is pre-warmed before being delivered to the rooms. During the warmer months this system can be bypassed, and warm air is flushed from the building. Despite this bypass, I happened to visit during particularly hot weather, and it appeared there was some overheating as most of the windows were wide open. Passive House certification requires that in the energy modelling the building is predicted to overheat (over 25 degrees C) for a maximum of 10% of the time. In countries with warm summers this is difficult to achieve in super-insulated buildings, and it is desirable to include passive measures for 'flushing' excess heat from the building, such as opening windows.

As well as designing Passive-House projects, Kaplan Thompson have completed several LEED-certified buildings, and have recently begun working on 'Living Building Challenge' projects. The latter certification attempts to provide a holistic framework for building a truly sustainable building: The criteria includes an extremely demanding material specification eliminating plastic-based materials and heavy metals. The standard demands consideration of the construction process, the number of miles materials are transported to site, high performance standards and consideration of deconstructing the building at the end of its life.

Conclusion

The Bayside Anchor building again demonstrates that it is possible to achieve a high-performance standard within an affordable housing budget. The project was achieved using an enhanced version of a familiar construction technique, and with a contractual arrangement that allowed for early collaboration between designer and contractor. The architects have recognised that there are more issues beyond that of performance, and in future projects are now attempting to consider the impact of material choice, embodied energy and the construction process.

Typical construction detail at Kaplan Thompson Architects

03 GO-Logic

Energy-Efficient Design and Build

Belfast, Maine

- **Commitment to Passive House-level performance for all their projects**
- **Ambition to streamline the Design for Manufacture process, and harness available technology to do so**
- **Plans to utilise local forestry resources and declining industrial facilities to locally produce construction materials**

G-O Logic is an architecture and construction firm based in Belfast, Maine. Their aim is to '*improve the quality of the built environment while significantly reducing building energy consumption and carbon emissions'* and their sister company G-O Home offers a series of prefabricated high performance standardised house designs. The company has achieved several Passive House-certified projects, and typically builds to the Passive House standard.

G-O Logic typically produces 12-15 homes per year, and at any one time has a waiting list of around 6 houses. I interviewed one of the G-O directors, Alan Gibson, at their offices and Alan then gave me a tour of their nearby production facility.

Off-site

The G-O Logic offices are based in the centre of the town of Belfast, and the off-site construction factory is a short drive away. The factory is a large former agricultural building where timber-framed panels are produced.

The panels are framed out on work tables, and sheathed externally with Ziplock™ board, which acts as an external air-tight barrier. Windows, doors and external insulation are installed in the factory. The panels are transported to site uninsulated between the studs in order that wiring and services can be run through the wall before insulation and internal linings are installed.

Adjacent to the factory floor is the production office where the house designs are processed into a three dimensional model, and the component panels are issued as drawings to the workshop. Alan and his employees highlighted that this is a part of the process that they would like to streamline further. Currently the design is remodelled from the architect's drawings, and the panel sizes are optimised for manufacture. The programmes used are Strucsoft, Solidworks and Rhino, but we discussed that in an ideal world, software could be used by the designer right from the start, which would then feed into the manufacturing process.

Passive House by G-O Logic
Source: G-O Website

Typical construction detail at G-O Logic offices

Materials

G-O Logic employ the typical timber framing methods common in New England, enhanced to meet a higher performance standard.

The timber they use is locally grown and the timber kit is generally 200mm deep. Cellulose insulation is pumped into the kit on site, and the entire house is enveloped externally with 150mm of rigid rockwool insulation.

G-O Logic are pursuing the manufacture and use of blown wood fibre insulation. It is proposed that locally available spruce and fir could be chipped, and insulation produced in existing facilities from the declining New England paper mill industry. If produced locally, wood fibre insulation boards could compete with oil-based insulation boards on cost and performance, as well as providing local employment.

Performance

The majority of G-O Logic buildings are designed to achieve Passive House criteria, although not all projects are officially certified.

The Passive House Institute of the United States (PHIUS) has slightly different criteria to the European Passive House Institute. Most notably, there is a requirement that both the criteria for space heating and the maximum heat load for the house are both achieved (in Europe it is one or the other). Although New England enjoys warm summers and benefits from a good deal of solar gain, the very cold winters make it difficult to achieve the heat load criteria, which is concerned with heating the house on the notional coldest day of the year for that geographical area.

G-O Logic have achieved the high performance envelope by enhancing a typical timber kit, and wrapping it in insulation externally. The process is still familiar to local construction workers, and therefore the more complex details for PH can be concentrated on.

Beyond their 'standard' specification, G-O Logic also offer upgrades, which include wood burning stoves, add-on porches, and photovoltaic arrays to create 'net zero' homes.

Conclusion

G-O Logic set a high building performance standard, and demonstrate a great deal of thought behind their construction system. Their material choice and future ambitions for insulation manufacture consider not only cost, but local manufacturing capability and locally available resources.

During my visit it was acknowledged that the design for manufacture process could be streamlined further, and that the current manufacturing facilities are somewhat limited in terms of space and automated machinery. Like many small businesses in the UK the investment required for improving off-site facilities is substantial.

Of the various companies I visited, G-O Logic appeared to be the most committed to setting a high-performance standard across all of their projects, and optimising their off-site system to meet Passive House levels.

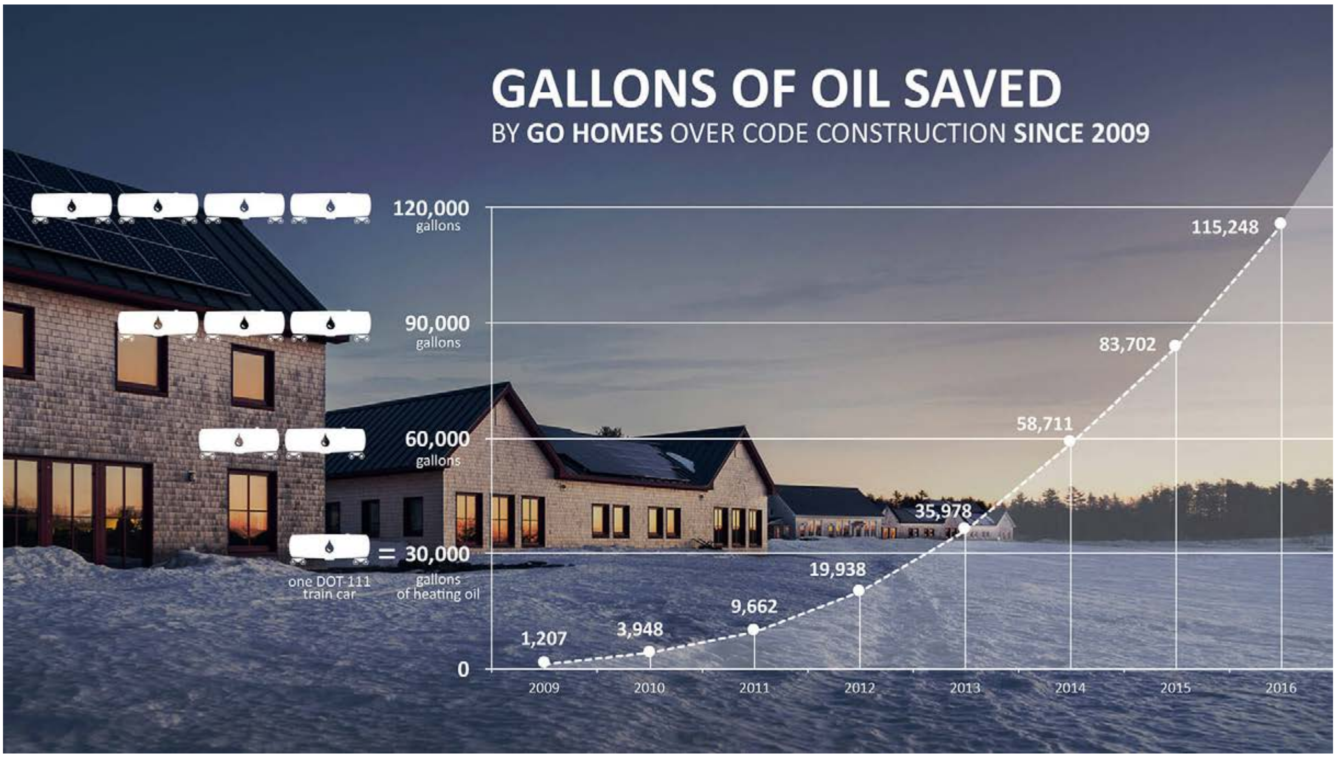


Illustration of energy savings provided by Passive-level construction
Source: G-O Website

04 Bensonwood | Unity Homes | Tektoniks

Custom Design and Build

Walpole, New Hampshire

- **Extensive design and modelling pre-manufacture, leading through to the production facility**
- **Customisable ‘platform’ houses designed for manufacture as a ‘kit of parts’**
- **Highly skilled teams undertaking clearly identified roles, and treating the next team as a ‘customer’**
- **Clear and thorough process from design through to manufacture through to assembly on site**
- **Use of advanced technology for cutting, labelling and manufacture**

Bensonwood is a progressive timber framing company based in Walpole, New Hampshire. Founded by Tedd Benson in 1973, the company designs and builds bespoke off-site timber-framed homes and buildings. Alongside Bensonwood, two sister companies operate: *Unity Homes*, launched in 2012, offers ‘platform’ based designs and customisable pre-designed house types; and *Tektoniks Advanced Building Components*, launched in 2018, offers the Bensonwood construction system as kits that can be applied to other architects’ designs.

The company has two facilities in Walpole, including a newly acquired 10,000m^2 production facility to cater for the growing demand from all three businesses. The original Bensonwood workshops now cater for bespoke joinery work and smaller components. The design offices are located adjacent to the original workshops, a short drive away from the new production facility.

I spent a day at their facilities meeting the founder Tedd Benson, and touring the offices and workshops with Operations Manager Hans Porschitz and Building Systems Team Leader Jay Lepple.

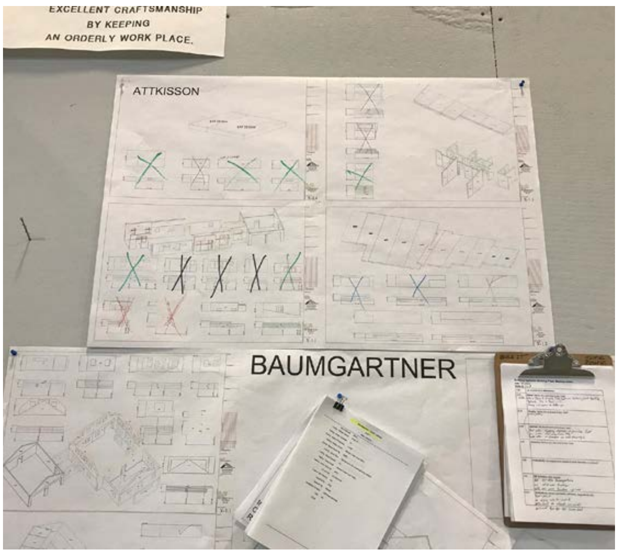
Off-site: The design process

The designers and engineers use extensive 3D modelling during the design and production information process, and this information is transferred to the factory-floor. The company currently uses a combination of the programmes CADwork and Revit throughout the early and detailed design stages. It was acknowledged during my visit that bespoke software was really required to ensure a smooth, value driven process with as little remodelling as possible during the design stages, and this was something they are working on for the future.

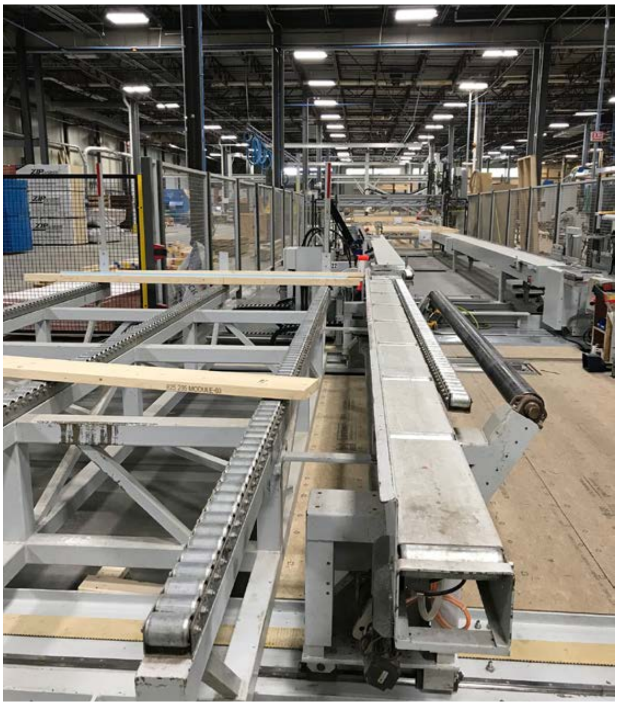
In order to make the Unity Homes 'platform' homes more affordable, they are partially pre-designed and optimised for off-site construction. A number of pre-designed three dimensional modules are used by the designers to create customised designs from this 'kit of parts'. There is an ambition that in the future this will lead to a three-dimensional module prefabrication process in the factory.

Off-site: The factory process

The majority of Bensonwood homes are prefabricated in panels, which are framed, insulated and sheeted in the factory before being transported to site. Automated cutting is used for the initial framing, and the panels are sheeted and insulated in a production line which makes use of lifting equipment and technologically-advanced tools. Windows, doors and thresholds are all installed in the vertically stored panels.



Current project information at the Bensonwood facility



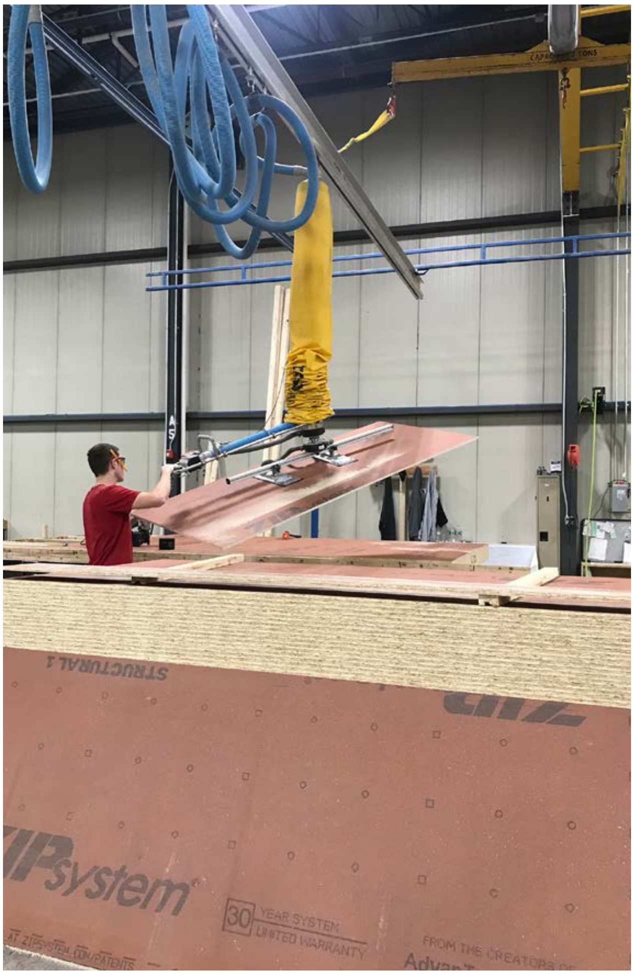
Framing line at the Bensonwood facility

On the factory floor communication is key: Around 30 people work there daily, and morning discussions are held to address the tasks and targets for the day ahead. There are 3D images displayed of the current house that is going through the workshop, where the numbered component parts can be seen coming together to make the finished article. Factors such as safety, quality, delivery, inventory and productivity are visually graded Green / Yellow / Red to represent Good / OK / Needs Work.

The factory is also a tightly run operation, with a Tektoniks kit available to ship 2-3 weeks after a finalised order is placed. There is a rotation of staff whereby those working in the factory also work on site, and can therefore see the result of their previous work in the next process.

Within the factory the operations are also tightly controlled. On the production line all components are labelled with a QR code and a list of attributes – part, panel, bundle. Timber cutting is automated, and timber is selected by an automated picker from pre-set lanes adjacent to the machine. As well as cutting to length, the saw (an SC3 Hundegger Speed-Cut) can also cut mortice and tenon joints, and print pre-determined guide lines onto the timber. These lines are used later to ensure the dimensioning and precision of the panel, which is vital for a smooth assembly on site.

Open filling panels with cellulose insulation



Lifting equipment utilised to move large sheets into place


Computer model marking on timber


CNC-cut timber joints

Materials

Bensonwood was inspired by the heavy timber framing of traditional New England houses, and it continues to utilise timber as its primary construction material. Traditional woodworking is coupled with technologically advanced machinery and computer-aided production to optimise their use of timber as far as possible.

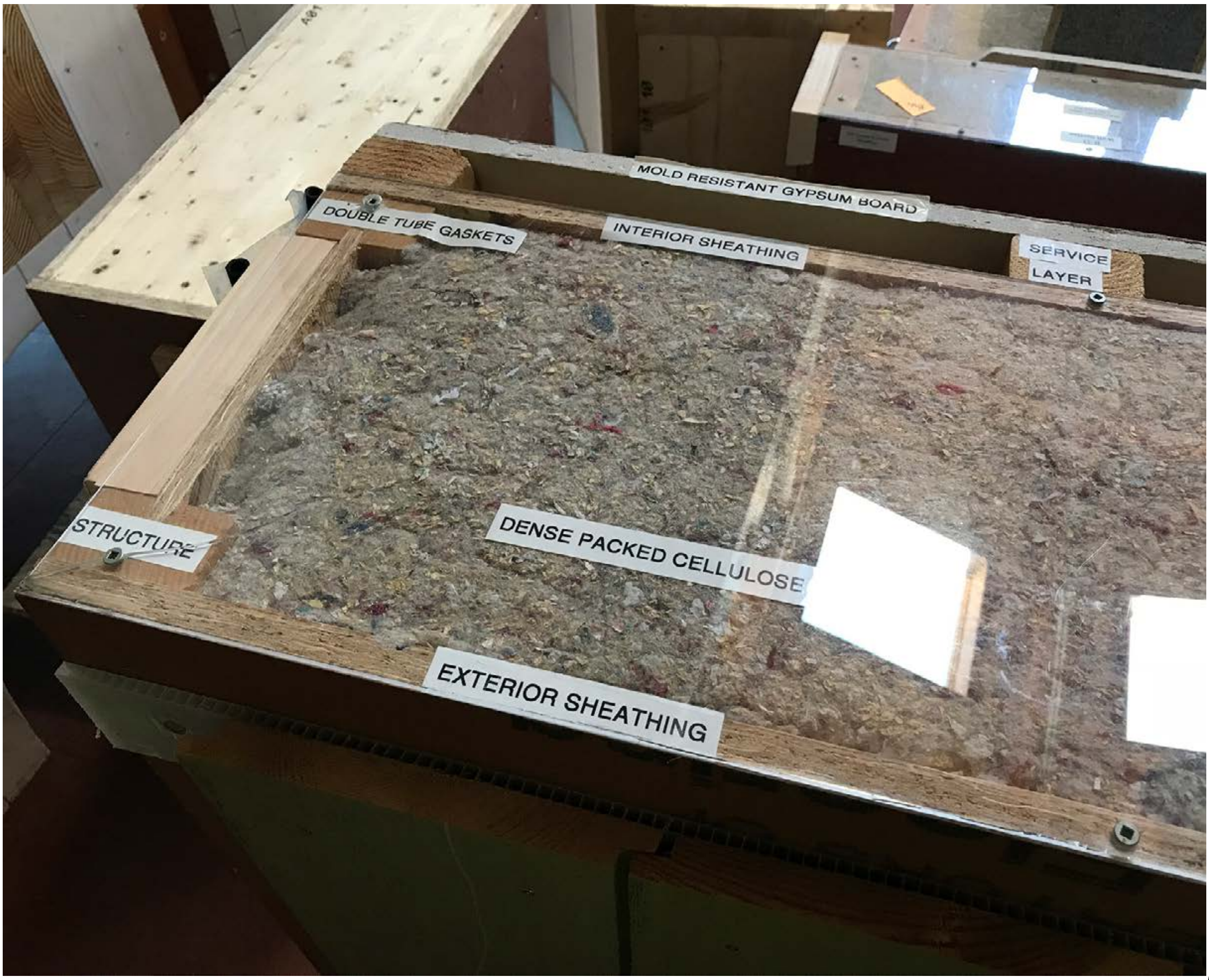
Cellulose insulation is installed in the open panels, with the framed panel lying flat on a table and cellulose applied to all the cavities. The density of the cellulose, which is key to its insulation performance, is measured by lasers during the production process. Externally there is the option to apply a continuous wood fibre board in order to improve thermal performance.

Performance

The proposition for Unity Homes is '*Neither compromise or maximize, only optimize'*. In summary they strive to offer systems that are the best performance whilst remaining affordable to ordinary people.

In terms of thermal performance Bensonwood have deliberately avoided designing their standard panel options to Passive-House level, although it remains an option. They feel that the final 10-15% required to achieve Passive House levels puts the cost beyond a reasonable level for ordinary people.

They have, however, kept options open, with four different wall types available, with varying stud depth (150mm – 220mm) and the option to include 2 ½ inches (60mm) of external wood fibre insulation.



Typical wall construction model at the Bensonwood show room

Conclusion

Bensonwood was an extremely impressive organisation to visit. Throughout my visit I was struck by the energy put into the entire process by each worker. Everyone I met was aware of their input to the overall operation, and clearly articulated their role in the company.

The integrated design process was clearly optimised to support the manufacturing process, although it was acknowledged that they would like to streamline the process further, and that they were considering bespoke software to join up the design and manufacture processes.

The off-site facility is also very impressive, with a mix of automation alongside knowledgeable and skilled staff.

The materials Bensonwood use are judged for availability, performance and affordability, and the available options allow for a degree of flexibility on performance and cost.

Overall Bensonwood, and its associated sister companies, demonstrate the optimum in designing and building high-performance buildings using modern construction methods and sustainable materials.

Vertical storage of panels at the Bensonwood facility

Findings from New England

During my time in New England I experienced two very different types of housing development, that of developer-led multi-family housing and that of custom or bespoke design and build companies. Both approaches offer useful lessons in providing high-quality housing.

Both multi-family projects used a contractual arrangement that allowed for early contractor involvement by way of a Construction Manager, allowing for key details to be designed and costed at a suitably early stage.

Whilst all the systems I saw, particularly the Passive House projects, required demanding detailing, all the companies used construction details that are enhanced or adjusted versions of traditional, familiar systems. Several times I was told that developers and architects wanted to use familiar techniques for the local workforce, and to make incremental changes.

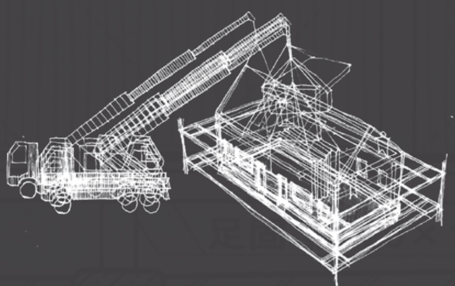
Within the design and build companies, where architect and contractor operate in collaboration, it was still recognised that the link between design and manufacture was an area that could be made more efficient. In particular the ability to design and manufacture from the same computer model, without the requirement to re-draw for manufacture, was something both companies were looking to achieve. This is something that has become commonplace in the engineering industry, but is still rare in construction.

All the companies had a motivation to keep costs low, either to meet government funding requirements, or for commercial reasons. The multi-family developments had tight, affordable-home budgets, whereas companies like Bensonwood have tried to finely tune their system to provide the best performance whilst remaining affordable for ordinary families.

Interestingly, the multi-family developments were not financially incentivised to build to higher performance standards by local Governments, rather the developers and architects were convinced of the long-term benefits. However, both projects did undertake measures to include an alternative income revenue from the building; both installed roof mounted photovoltaic panels that will provide an income for years to come.

In the case of the multi-family developments, it was possible to achieve Passive House certified buildings, in part, due to the better thermal performance of apartments that share floors, walls and ceilings. One of the main criteria for Passive House is to limit heat loss through the envelope, and if the ratio of the external envelope to internal volume is low, this means that the thermal performance of the floor, walls and roof can be comparatively reduced. This leads to a cost savings in materials when compared with the thermal performance required for a detached house with a high envelope to volume ratio.

My lasting impression of the New England case studies was the drive to achieve the balance between costs and the best performance possible, with a variety of solutions demonstrated.



On-site panel assembly

Fellowship Conclusion

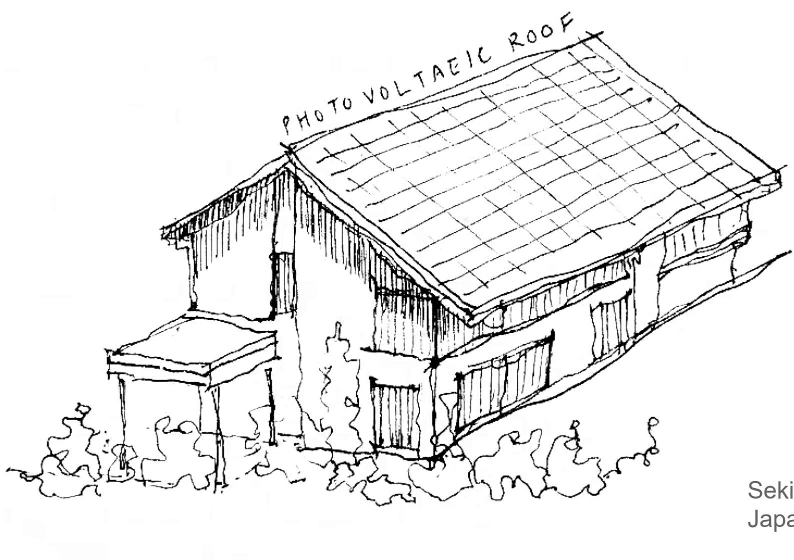
The aim of my Fellowship was to investigate how others construct sustainable, high performance homes using progressive timber off-site construction methods. I found a wide range of interconnected approaches, and as such I did not find one perfect solution. Rather my Fellowship delivered a collection of useful lessons.

I found strong examples of design and construction being closely related, particularly in companies that control both the design and the construction processes. When this was not the case, high performance buildings had been achieved through specific contractual arrangements that allowed early collaboration between designer and manufacturer/builder.

Many times I observed an awareness and knowledge of materials, and active supply chain management. From owning a foreign forest to rejuvenating depressed local industry, the house builders I met were actively engaged with their supply chain. Although local materials were generally favoured, cost was often cited as the reason for using imported materials.

I had expected to find that energy-efficiency was top of the agenda for most house builders, and I was surprised as I discovered this wasn't necessarily the case. However, I came to appreciate the 'performance' of a building was valued in different ways, and that the house builders I met had a variety of priorities. What I did find was that when energy-efficient performance, such as Passive House, was highly valued by clients and developers, this motivated practitioners to find innovative ways to achieve the tough criteria. I witnessed a huge amount of collaboration and shared learning in both countries. I also witnessed the huge amount of investment undertaken by Japanese house builders into research and development into their priority issues.

My travels introduced me to a rich collection of ideas and approaches. Although I write from the perspective of an architect, the lessons I learnt are also be applicable to builders, developers and policy-makers. Overleaf I have outlined a summary of recommendations for the UK.



Sekisui Zero Energy House
Japan

Recommendations

The recommendations from my Fellowship are broad ranging, and require the input of many stakeholders including architects, contractors, developers and policy-makers. In many ways this reflects how our current, disjointed, way of working prevents us from really pushing forward in the areas of sustainable and affordable housing provision.

There are many good reasons to consider building off-site. However, there are significant barriers to its uptake including a lack of funding for facilities and a lack of understanding of designing for manufacture. From my travels I would recommend the following:

- **Encourage the development of off-site and manufacturing facilities**
  Funding is required for construction companies to invest in off-site facilities, machinery and skills training. This could take the form of loans, grants or be propelled by project-specific requirements.

  It has been reported that a lack of uptake in off-site construction in the UK is in part caused by the high capital investment required, and the financial investment was referred to by practitioners I met during my Fellowship.

  Companies such as Bensonwood, who have been able to invest heavily in their facilities are now able to offer their product to a wider range of customers. Their machinery and skills base allows them to ‘optimise’ their product to perform highly at the lowest possible price.

  Ideally we require factories that are automated to the extent that labour savings are made, and the factory workers are highly skilled in working with the technology. This means that we need investment not only in physical facilities and machines, but also in people and skills training.

- **Invest in the development of specialist software and Building Information Modelling linked to off-site manufacture processes**
  In Japan I saw several companies who have developed their own software which feeds directly into the off-site construction system, allowing a house to move through the factory within a matter of hours. In New England several Design and Build companies referred to the fact that they had reached the point of requiring specialist software that would allow bespoke or customised designs to be drawn up within the parameters of the off-site system, and to feed directly to the factory floor.

  From my own professional experience I am aware that small design changes early in the process can significantly affect the off-site production process. If we want to use off-site construction at a larger scale across the UK, and in an efficient manner, it is necessary that designers are able to design within the parameters of off-site construction from the early stages.

  I would propose that funding needs to be made available for off-site manufacturers to produce modelling software that can be made available to designers, streamlining the Design for Manufacture process.

From my professional experience I hold the view that timber is a sustainable and appropriate material for house construction in the UK. I found during my Fellowship that local materials in general can be beneficial to local industry, especially when developed by local practitioners to be appropriate for the climate. I would therefore recommend that:

- **Encourage the use of locally produced materials in house building, in particular timber**
  In Maine I found that there is an ambition to use locally-available forest products as well as the locally available manufacturing resources in terms of population and facilities.

  In the UK, despite forest cover representing a smaller proportion of land, we do still have the potential to utilise forest products for construction. In particular we can utilise our homegrown forest products to develop engineered timber products, thereby benefitting both the forestry and construction industries.

  If house construction were encouraged to use timber as its principal construction material this would significantly benefit both the carbon footprint of the build, as well as providing healthier living environments for the future.

- **Encourage research and development of components and materials that we currently need to import from abroad**
  In Japan I found practitioners taking Passive House products that had been developed abroad, and working with local manufacturers to produce similar products best suited to the Japanese climate.

  In the UK a similar task could be undertaken in the form of partnerships between academia and industry. Rather than private companies funding their own research institutes, we should encourage public institutions, such as the Construction Scotland Innovation Centre, to develop progressive and efficient products that are best suited to UK climate requirements and building processes.

The main driver of improving energy performance is in order to reduce energy use, and therefore reduce greenhouse gas emissions. My travels also highlighted the many other factors of ‘performance’ that are valued in different parts of the world.

- **Increase base thermal performance levels in the building regulations**
  The required energy-performance levels in the building regulations need to be improved if we are to have any chance of meeting our legal obligation to reduce greenhouse gas emissions by at least 80% of 1990 levels by 2050.

  By placing this demand on new housing we can achieve a significant reduction in our space heating requirements. (It is recognised that we must also look to improve existing housing stock, although this is outwith the scope of this Fellowship).

  It follows that houses with low space heating demand in turn require less space heating equipment to be installed, and therefore reduce the requirement for maintenance and upgrading in years to come.

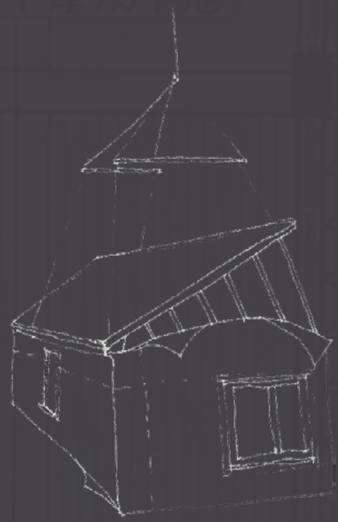
Additionally it is widely recognised that flatted and terraced housing have lower energy requirements due to sharing party walls. Twice in New England I found that it is possible to achieve ultra-low energy housing within affordable budgets. Building regulations should therefore place more demanding energy performance requirements on these building types, in the recognition that they are easier to achieve. A significant proportion of social and affordable housing is developed using flatted or terraced building types, therefore this would benefit those with lower incomes.

- **Encourage early collaboration between design consultants and contractors through contractual arrangements.**
  I saw two projects in the US that specifically used a Form of Agreement between the Client and Contractor, which meant that a Construction Manager was brought on board early in the process, whilst design was ongoing. This arrangement allowed the Construction Manager to determine suitable sub-contractors, who were able to deliver the quality of work required for Passive House, whilst the design process was ongoing. Typically the works were then undertaken under small separate contracts, meaning that sub-contractors still had to tender for work packages, ensuring that costs did not spiral out of control.

  If developers required a similar Form of Agreement to be used in the UK we could achieve a very similar scenario whereby there is expert construction input during the design process, ensuring that key quality criteria are not lost during a later cost-cutting exercise as a result of a high tender return. Additionally it allows ongoing design input whilst the project is on site, unlike what typically happens under Design and Build contracts, whereby designers are employed by the contractor rather than the client.

  In turn this would give developers the confidence to demand high-performance in their briefs, without the fear that the performance will inevitably be reduced when tenders come in too high.

From my Fellowship I am convinced that the adoption of some or all of the above recommendations would provide a significantly more effective model for the provision of high performance housing in the UK, which is safer to construct, healthier to live in and kinder to our environment. To change our current way of working would require the adoption of the collaborative spirit I found in both Japan and New England between designers, developers and contractors.



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