Building sustainable homes at speed

Risks and rewards

Research Review

NHBC FOUNDATION

Housing research in partnership with BRE Trust

48

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About the NHBC Foundation

The NHBC Foundation was established in 2006 by the NHBC in partnership with the BRE Trust. Its purpose is to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation's work has focused primarily on the sustainability agenda and the challenges of the Government's 2016 zero carbon homes target. Research has included a review of microgeneration and renewable energy technologies and the earlier investigation of what zero carbon means to homeowners and house builders.

The NHBC Foundation is also involved in a programme of positive engagement with Government, development agencies, academics and other key stakeholders, focusing on current and pressing issues relevant to the industry.

Further details on the latest output from the NHBC Foundation can be found at www.nhbcfoundation.org.

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Foreword

It is perhaps an irony that the title of this report refers to building homes at speed when our current annual housing output is at one of the lowest levels in recorded history. However, the growing need for more homes to be built, along with the house-building industry's focus on building more sustainable homes, makes this a good time to consider some of the potential issues arising from the combination of innovative construction and building at speed – before the pressure to do so really impacts. Even though recovery of the industry and the wider construction sector is likely to be long and slow, interest in innovative forms of construction to meet sustainability requirements are expected to feature prominently in the coming years. Unfortunately, our record in the UK of introducing innovative construction that achieves robust, long lasting solutions has been mixed.

As a sector, all parties to the provision of new homes including policy makers, designers, developers and the supply chain, we have a responsibility to the end user of the homes we build – whether home owners or social tenants – to produce homes that are truly fit for purpose and meet the reasonable aspirations and expectations of those that occupy them. This research review seeks to identify some of the risks and rewards of innovative construction methods across a number of pioneering schemes. These schemes have had speed of construction at the centre of the design rationale, and the intention is of assisting those involved in future schemes to maximise the rewards and minimise the risks – both to the providers and the eventual occupiers.

Rod MacEachrane
Director, NHBC Foundation

1 Introduction

New construction techniques have presented the house-building industry with the opportunity to combine the benefits of building quickly and sustainably, meeting the requirements of the higher Levels of the Code for Sustainable Homes while delivering a consistent level of performance. House builders considering using such systems are faced with difficult judgements about whether innovative systems can deliver their objectives. Shorter construction programmes may often be an explicit aim of both registered providers (RPs) and private house builders, looking for a rapid return on investment, or faced with developing a constrained or sensitive site where a prolonged construction stage may be problematic. In many cases, rapid construction is not a primary driver for a project, but is nevertheless a welcome consequence of using modern methods of construction (MMC) systems which have been chosen for other reasons, such as specific environmental benefits.

Whatever determines the selection of MMC systems, clients, design teams and contractors need to be prepared to cope with rapid construction methods and different ways of working. The implications of moving a large part of the construction process away from the building site are significant and many of the problems encountered when attempting to build quickly can be linked to a failure of clients and design teams to appreciate the consequences.

Over the past 30 years a number of systemic building failures have come to light which has led to suspicion of MMC in some quarters, notably the failure of precast reinforced concrete houses in the UK[1]. Against this background, the MMC manufacturers and designers who work with these systems must be ready to take steps to ensure that clients are presented with durable, low-maintenance solutions which will provide a healthy internal environment for occupants over the lifetime of the building. This means not only achieving certification and accreditation of products, but also ensuring that building designs are optimised to suit construction methods and that high standards of installation are rigorously applied.

The urgent need for new housing to accommodate a growing population remains a pressing issue. Annual housing completions stood at 177,000 in the year ending December 2007. Against the background of the recent recession, completions fell through 2008, 2009 and 2010 with 107,000 completions recorded in the year ending December 2010. Since 2010, completions increased only slightly and stood at 117,190 in the 12 months to September 2012[2]. Countries such as Germany, the Netherlands and Sweden have far outstripped the UK in the quantity of housing they have built in recent years. The reasons for this are many, and they are as much to do with how development and associated infrastructure are planned and funded as they are to do with construction methods. However, some innovative methods used on recent UK projects originate in Europe and despite differences in the regulatory framework in the UK, examples such as the Stadthaus (see section 2 case studies) have been successfully implemented with significantly reduced build times compared with conventional methods.

2 Case studies

The case studies included in this research review set out the lessons from selected sustainable housing developments which had the potential to achieve significant gains in construction speed using innovative approaches.

The research review summarises and prioritises the risks that house builders, RPs, manufacturers and design teams should be aware of when considering how to build sustainable homes quickly, highlights the risks that are of most concern and suggests how the most significant risks can be avoided or mitigated.

2.1 Adelaide Wharf

Project details	Adelaide Wharf
Project location	Hackney, London E2 8PD
Project dates	Work began onsite in April 2006, completed in October 2007 and the first residents moved into the apartments in November 2007
Project size	0.43 hectare site; gross floor area: 14,379 m^2
No. of units	147, one-, two-, three- and four-bed mixed tenure apartments
Project value	£22 million
Developer/client	First Base
Main contractor	Bovis Lend Lease
Subcontractor	Unitised cladding panels, Sipral UK
Bathroom pods	OEP Raterad
Reinforcement carpet	Bamtec
Architect	Allford Hall Monaghan Morris
Structural engineer	Adams Kara Taylor

Figure 1 Adelaide Wharf

2.1.1 Summary

The developer's brief required efficient, rationalised design and MMC. The designer's response was a simply organised plan using pre-fabrication techniques, perhaps more commonly associated with office, retail and hospitality sector developments. Measures adopted included a unitised cladding system (Figures 1 and 2), pre-fabricated bathroom pods, balconies and plant, and roll-out slab reinforcement carpets. The design evolved from prototypes designed for developer First Base's London-Wide Initiative bid[3].

The time available at the start of the project for researching an appropriate design solution was unusual and an important part of the project's success. The international reach of the main contractor was another contributing factor, enabling the sourcing of usually expensive products more economically.

Figure 2 Unitised cladding panels

Construction programme savings were achieved, although the amount of work required to finalise the design of complex elements, such as the unitised cladding system, was considerable.

2.1.2 Programme

After land remediation, the build was completed in 16 months. This included two months for removing an existing concrete basement. The client, First Base, estimates that as a result of using MMC, construction cost and delivery time were both reduced by 20%.

2.1.3 Construction approach

Unitised cladding panels

Curtain walling systems incorporating glazing and other cladding materials are usually procured as stick systems – stock lengths of extruded profile are delivered to site with subcontractors assembling the façade. However, unitised systems are delivered as fully assembled panels. Considerable effort is often required to design and detail the systems, but once onsite, unitised panels can be much quicker to install. Systems are specified for commercial buildings with repetitive, often fully glazed façades, but use on residential projects is unusual.

Bathroom pods

Traditional bathroom construction requires a large number of trades often working independently and overlapping onsite: tilers, floor layers, plumbers, electricians, sealant applicators, decorators, glaziers and joiners may all be involved and the sequencing and management of their work can be complex and time-consuming. Bathroom pods can simplify construction by taking these activities offsite (in this case, out of the UK), where manufacturing can occur in a cleaner environment with a high degree of quality control. Pods are then delivered according to an agreed schedule and craned into position onsite.

Slab reinforcement carpets

Reinforcement carpets replace traditional slab reinforcement. They are manufactured offsite, where the process can be automated using information imported from finite element software, incorporating a high degree of complexity using factory welds rather than ties. Reinforcement carpets were developed because the most efficient design of concrete slab reinforcement is often constrained by the practicality and affordability of cutting and bending complex arrangements of reinforcement steel onsite. Once delivered to the site, they can be craned into position and rolled out.

Design and implementation

Architects Allford Hall Monaghan Morris, along with Bovis Lend Lease and First Base, worked together to develop the construction approach (Figures 3 and 4). The objective was to reduce trades, interfaces and construction time onsite. The London-Wide Initiative bid submitted to English Partnerships was fully costed with proposals tested with trade contractors to improve buildability and to identify further efficiencies. The intention was that this construction approach should be used again on future projects, subject to its success at Adelaide Wharf.

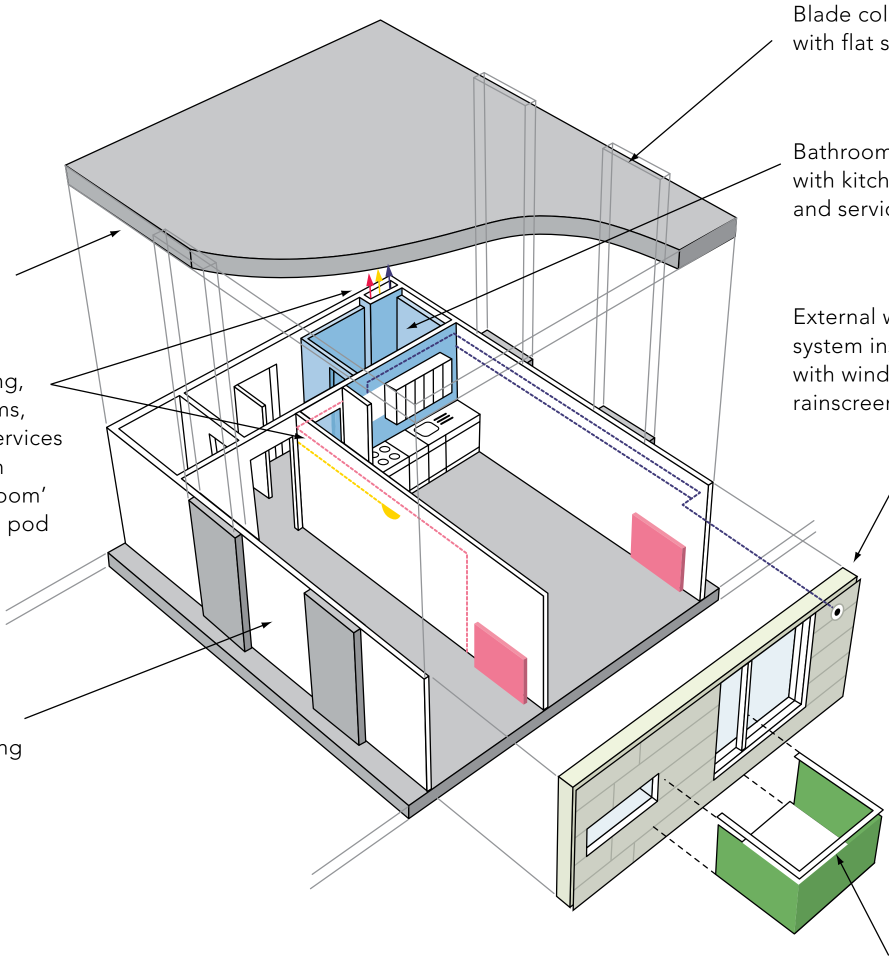

Figure 3 The building system developed for Adelaide Wharf (based on an original illustration supplied by Allford Hall Monaghan Morris)

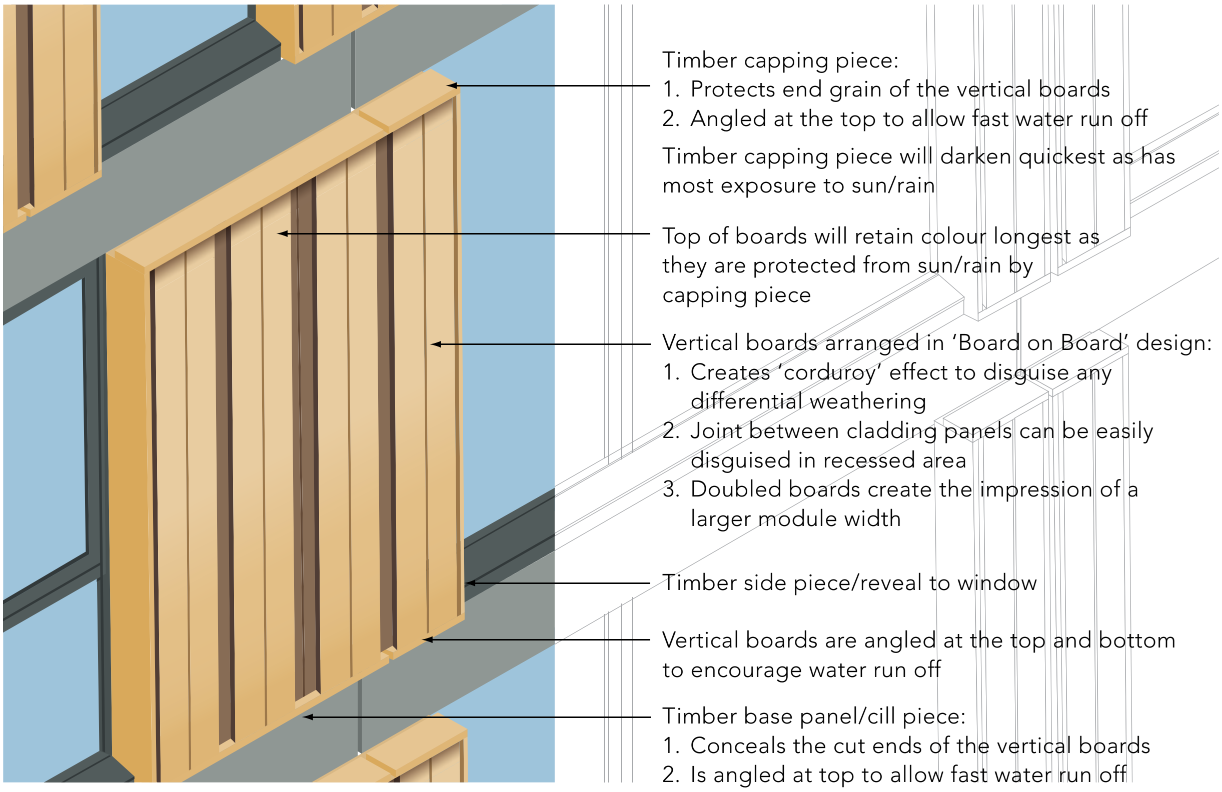

Figure 4 Detail of the unitised cladding panels (based on an original illustration supplied by Allford Hall Monaghan Morris)

More extensive pre-fabrication of the structure was considered. However, there were limiting factors which meant large-scale implementation would be difficult: pre-fabrication is usually most cost effective when repetition is involved. While aspects of the scheme, such as bathroom layouts, were repetitious, the shape of the site and the mix of varying apartment types meant that structural flexibility was required. In-situ concrete was preferred, with thin 'blade' columns placed in party walls to reduce physical protrusions into occupied areas.

Sipral UK was responsible for producing the unitised cladding panels. Units measuring 3.5 m x 2.9 m were manufactured in Prague using Schuco's curtain walling system and incorporating Siberian larch cladding boards. These were then shipped to site and installed without the need to erect a scaffold.

Bathroom pods were manufactured in Poland by OEP Raterad. These were installed before the external cladding arrived and were plumbed into a centralised heating and hot water system.

2.1.4 Risks

Unitised cladding system

Design time was considerable. Pre-fabricated buildings are often criticised for being bland; a conscious effort was made to reduce the visual impact of repetitive vertical joints between panels which meant designing panels to disguise joint locations and varying panel designs. Balcony fixing details were also incorporated, which meant that very few panels were identical.

Figure 5 Packaged unitised cladding panels (© Allford Hall Monaghan Morris)

The fact that panels varied considerably and were not interchangeable meant that precise sequencing of construction had to be managed. Construction started at the ground floor and continued up the building with panels installed from the inside.

Using timber cladding on this scale posed risks. Durability issues and differential weathering were a concern. With a panelised approach, repetition of bad detailing can make the problem worse. To resolve the differential weathering issue, boards were arranged in a 'board on board' design (Figure 5). Joints between panels were concealed in the gaps between boards. A timber capping piece was used to shed water and protect the end grain of the boards. The construction and inspection of mock-ups were an essential part of the sign-off process.

Bathroom pods

Design work was carried out with a supplier of bathroom pods early in the process. It generally makes sense to start working with suppliers as soon as possible: an early design freeze is important for this sort of offsite manufacturing, and drawing on the expertise of the supplier helps to reduce their overall price and establish cost certainty. The risk of this approach is that the design solution becomes focused on one product – a risk because, for a variety of reasons, the supplier of that product may not see the job through. This was a problem encountered at Adelaide Wharf, when the proposed pod supplier withdrew. An alternative supplier (OEP Raterad) was rapidly identified and designs were successfully modified.

One of the main design impacts of the switch in suppliers was the change from floorless pods to pods with steel plate floors. The steel plate floors were very thin so the hope was that raised thresholds could be avoided without the need for a thick screed. In the event, the finish on the slab was not as even as expected and a screed was required.

Pods were craned up the façade of the building and slid onto floor slabs from the side before cladding was installed. Floorplates were therefore not watertight and pods had to be left exposed to the elements for a period. Holes through the floor slabs allowed water to drip through the structure onto the pods below. The architect felt that it would be relatively easy to protect pods on future projects.

The intention was that the comprehensive specification of the pods would mean that trades people would not need to enter the pods at all during construction. Any work required to plumb in the pods and complete any other installation works could be carried out from the outside and the interiors could remain untouched and undamaged. However, pods were accessible and contractors found it necessary to enter, although the reasons for this were not clear.

Reinforcement carpet

The reinforcement carpet was seen as a partial success by the architect, but did not offer significant time savings on this project. Variations in slab thickness from block to block, holes in the slab and the irregular column grid meant that a variety of different reinforcement details were required. Installation of the carpet was complicated and slowed by these variations. A simpler structural design would have better suited the product, but other design considerations made this impossible.

Unforeseen site constraints

English Partnerships levelled the site before First Base took control, but the additional work required to clear the existing concrete basement caused a two month delay. The impact of ground conditions when developing inner city sites such as this cannot be accurately predicted.

2.1.5 Rewards

Unitised cladding panels

Delivery was efficient and site storage of materials limited. The architect advised that at the peak of the installation, one cladding panel was craned into position every 15 minutes.

This solution was well suited to the constraints of the site which prevented scaffolding being erected on the northern façade, immediately adjacent to a canal. Thermally broken light steel frame systems were considered, but there was a concern that these would still require external working – a solution that allowed fixing from the inside was required.

Creative detailing allowed balconies to be fixed onto the unitised cladding panels rather than through them onto the structure behind. This accelerated the construction process because programming allowed balconies to arrive onsite after the cladding had been installed, rather than requiring the installation of the balconies before cladding could be completed. This approach also avoided cold bridging through the building envelope.

Bathroom pods

The client was able to benefit from the labour cost advantage of having the bathroom pods constructed in Poland. (Similar benefits were gained from having the unitised cladding constructed in the Czech Republic.)

The snagging process was simplified for the architect by inspecting and signing-off examples for the manufacturer in the factory in Poland. The risk was that anything missed on these inspections could become a defect that was repeated on many units, but the quality and finish achieved was generally of a high standard.

Procurement method

A design and build contract was used, but the design team felt that it was more like a traditional contract. The architect speculated that perhaps because Bovis Lend Lease (the contractor) was a major shareholder in First Base (the developer/client), there was a greater focus on quality and detail. The result was a less adversarial relationship between protagonists and a determination to solve problems.

2.2 The Stadthaus

Project	The Stadthaus
Location	24 Murray Grove, Hackney, London N1 7FB
Dates	Completed in 2009
Size	The site area is 17 m x 17 m and bounded on all sides by other residential buildings
No. of units	8 floors, 29 apartments
Value	£3.8 million
Client	Telford Homes PLC and Metropolitan Housing Trust
Main contractor	Telford Homes
Architect	Waugh Thistleton Architects
Structural engineer	Techniker/Jenkins & Potter
Mechanical engineer	Michael Popper & Associates/AJD Design Partnership
Planning consultant	CMA Planning
Timber supplier/ subcontractor	KLH UK

Figure 6 The Stadthaus (© Waugh Thistleton Architects)

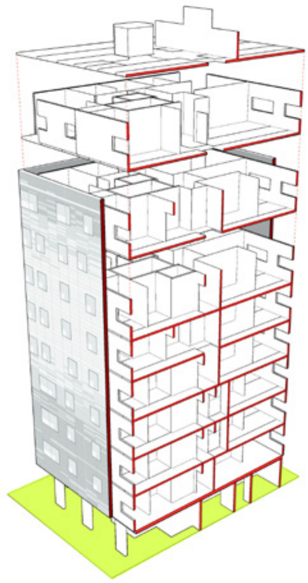

Figure 7 Cross-laminated timber loadbearing walls and floors (© Waugh Thistleton Architects)

2.2.1 Summary

The Stadthaus was the tallest timber residential building in the world when completed in 2009 (Figure 6). The nine-storey building was the first of its type to be constructed using cross-laminated timber (CLT) panels and demonstrated a form of construction that was relatively new to the UK (Figure 7). From the first floor upwards, loadbearing walls, floor slabs, stairs and lift cores were made entirely from timber. The designers' objective was to demonstrate the benefits of this material and to show how it could be used successfully for high density, inner city housing projects. The Stadthaus houses 29 apartments with a neighbourhood office on the ground floor.

There are no precedents for the Stadthaus in continental Europe because fire regulations relating to timber construction have prevented towers of this type. Design teams using CLT are required to design with the properties of the material in mind rather than with a steel or concrete frame mindset. Speed of construction was impressive, but it could have been improved. Post-occupancy feedback was positive and few defects were reported.

Research by Stadthaus structural engineers Techniker, suggests that if the platform approach used for the Stadthaus were to be carried forward on taller buildings, a 15-storey scheme could be achieved with economic wall thicknesses.

Following in the footsteps of the Stadthaus, another CLT housing project was constructed in Hackney – Bridport House, the first part of the regeneration of the Colville Estate, it became the second major CLT residential development in the UK.

The cost of CLT relative to steel or concrete alternatives will inevitably be weighed against its advantages.

2.2.2 Programme

The project team estimated an equivalent concrete building would take 72 weeks to construct. The CLT solution required only 49 weeks. Working onsite three days a week, a team of four contractors from Austria erected the timber superstructure of the building in a total of 27 days over a nine-week period. The building was occupied ahead of programme in January 2009 at a cost of £3.8 million (approximately £1400/m^2).

2.2.3 Construction approach

A good account of the construction of the Stadthaus can be found in *A Process Revealed/Auf dem Holzweg*[4].

Cross-laminated timber

CLT has been in use for some time in continental Europe but is a relatively new product to the UK. CLT is currently imported from Germany, Austria and Switzerland. The structural properties of CLT are a result of the way the material is manufactured. Planks of softwood are cut and finger jointed into strips. These are then stacked and glued under high pressure in perpendicular layers to produce panels. Solvent-free and formaldehyde-free adhesives are available. Panel rebates and openings are cut by computer numerical-controlled routers prior to transportation. Panels can be up to 20 m long, but are usually restricted to a maximum of 13.5 m for economical transportation to the UK from Europe and to allow for delivery by road without the need to notify highway authorities. The structural characteristics of CLT are detailed in Table 1.

Table 1 Span and height capabilities of mainstream structural materials in multi-storey buildings[5]

Material	Span	Height
Concrete	9 m for solid slabs	> 100 storeys
Cross-laminated timber panels	8 m for panels	12 storeys
Masonry	7.5 m for hollow core floor	7 storeys
Platform timber frame	6 m for engineered timber joists	7 storeys or 20 m
Steel	7 m for metal deck floors	> 100 storeys

Austrian firm KLH supplied the CLT for the Stadthaus and provided the contractors to erect the superstructure. The CLT panels were manufactured and cut to the architect's specification in KLH's factory in Austria, including door and window openings, before being shipped to the UK. Twenty journeys were required. On arriving at the site, each of the panels was unloaded with a mobile crane and directly lifted into position.

A simple platform construction method was adopted with walls secured onto the floor below using screws and angle plates. The panels were protected by an Eternit board rainscreen cladding on the outside and a dry lining system internally (Figure 9).

More detailed guidance on the design and construction of CLT structures is given in GD 10: *Cross-laminated Timber (Eurocode 5) Design Guide for Project Feasibility*[6], and *Worked Example: 12-storey Building of Cross-laminated Timber (Eurocode 5)*[7].

Figure 8 The Stadthaus under construction (© Waugh Thistleton Architects Ltd)

Figure 9 Exposed cross-laminated timber loadbearing walls and floors (© Waugh Thistleton Architects)

2.2.4 Risks

There are a number of risks, real and perceived, associated with the use of timber when used in place of traditional materials such as concrete, masonry or steel. Telford Homes sent four staff to Austria to witness the manufacturing process and discuss the properties of CLT with the supplier. Some of the concerns arising during the Stadthaus project are listed below.

Stability and movement characteristics

Given the height of the proposed structure, this was a particular concern. However, the following properties of a CLT structure prevent movement:

- The perpendicular arrangement of lamellas in each layer of timber and the way these are glued means swelling and shrinkage are minimised. Floor-to-floor movement due to moisture and creep at the Stadthaus was estimated to be 3 mm.
- Laminated construction means panels are very strong and loads can be carried in all directions. The structure works as a three dimensional system of interlocking timber plates. All vertical wall elements are used as shear walls (Figure 7).
- By avoiding concrete cores, differential movement that may occur with a conventional timber frame, does not have to be resolved.

Durability and technical approvals

The European certification held by KLH for the CLT panels was not fully acceptable to NHBC as it covered only a 50-year lifespan and NHBC required 60 years.

Telford Homes received approval from NHBC, with the backing of an extensive report from BRE (which manufacturer KLH commissioned), appraising durability over more than 60 years. NHBC subsequently provided a warranty for the Stadthaus project stating that it was the first pilot residential scheme constructed entirely from CLT panels from the first floor upwards.

KLH's European Technical Approval (ETA 06/138) is based on an assumed intended working life of the solid wood slab of 50 years.

A concrete and steel option was also developed for the project. This option was to ensure that a fall-back position was in place to guarantee programme objectives could be achieved should approval not be forthcoming.

Timber is potentially susceptible to rot, fungus and insect attack, however, the KLH CLT panels are factory dried to ensure low moisture content (under 12%) to prevent problems created by moisture arising. The project team was aware that the build-up of moisture behind cladding can cause problems. With the cooperation of KLH, detailing at walls, roofs and window openings were checked throughout construction.

Disproportionate collapse with panelised structures

When the Stadthaus was designed, no official guidelines were available relating to CLT structures. The structural engineer, Techniker, took advice from TRADA and the UK Timber Frame Association to come up with a method combining adequate tying and partial removal of elements. Rather than developing details for ties between units to provide sufficient strength to resist blast loads or unexpected impacts, the team decided to exploit the over-structuring of the building to plan for alternative load-paths should any component be compromised. Only two bracket/plate details and two types of screw were used throughout the whole building, with the exception of bespoke fixings between concrete ground and timber first floors. Therefore risk of onsite error was reduced and less site supervision was needed.

The design approach involved using overlapping tracing paper and colour-coded plans to determine optimum load-paths down through the varying floors of the building, while ensuring sufficient redundancy in the structure. Concrete used for the ground floor offered an efficient transfer structure to distribute the loads from above into the ground, though this storey was slower to construct.

Acoustics

The density of CLT works in its favour. This is much higher than traditional timber frame (50 kg/m^2 for a 100 mm panel). NHBC required sections of walls and floors to be built for testing. Building Regulations Part E *Resistance to the Passage of Sound*[8] requirements were achieved with two layers of plasterboard applied to each side of party walls; for the floors, layered and compressed insulation under a 55 mm screed was sufficient (this was also used for distributing underfloor heating). While this was deemed to be an effective solution, the use of a screed introduced a comparatively slow, wet trade.

Fire risk

In the event of a fire, CLT is offered protection by the outer charred layer so does not suffer in the same way as a joist or stud. Three-layer panels (the thinnest panel) can achieve F30 protection (maintain structural integrity for at least 30 minutes in a fire). Five layer construction achieves F60 protection. Protection is further increased to 90 minutes with two layers of plasterboard.

Three months after completion there was a small fire at the Stadthaus which was traced to a light fitting in a ceiling left on in an apartment by an absent tenant. Damage was limited to a small area of the ceiling with minimal penetration. Subsequently, following a fire officer report, light fittings elsewhere in the building were replaced.

Deadline for an early design freeze

All major service runs (ventilation ducts, gas pipes, boiler flues and electrical incoming supplies) have to be sized, drawn and communicated to the supplier so these can be cut out prior to shipping. This can prove very challenging. There is some limited scope for adjustment onsite, but repetition of incorrect detailing can amplify the problem. At the Stadthaus, a handsaw was used to adjust the fall on flue pipes for every unit.

KLH has the capacity to cut chases for service runs into the CLT panels during the production process. Plasterboard can then be screwed directly onto the panels. However, at the Stadthaus, services design had not been progressed far enough before commitment to panel design was required and so this approach could not be adopted. Instead, plasterboard was fitted to the panels on top hat sections with services surface-mounted in the gap behind with screw-fixed straps – a slower and more costly process. The gap also prevents the dwellings benefiting from the thermal mass properties associated with CLT. Early appointment of a services engineer would have helped the team progress the design further so more work could have been undertaken offsite by KLH.

KLH UK states[9] that the lead in time is normally 12 weeks:

- Six weeks for producing and commenting on drawings (two weeks if no revisions are made)
- Six weeks for production of panels, delivery to site and organisation of onsite activities (ie labour and crane)
- Additional three to four weeks if structural design is required.

Sequential rather than parallel construction work

KLH largely completed the timber superstructure before other packages of work began on the building. The programme could have been reduced if trades had overlapped with a potential saving of eight weeks). However, KLH did not allow for any interface with other trades (other than scaffolding operatives) while the KLH programme was still in progress. External scaffolding was required at the Stadthaus to allow installation of the Eternit cladding system.

2.2.5 Rewards

Other than the speed of construction, further benefits of the CLT construction route were exploited as follows.

Tolerances

Construction tolerances are smaller than that achievable with concrete. Typical concrete tolerances of 10 mm compare with +/-5 mm achieved with the Stadthaus. Good tolerances simplify construction and cladding, save time and help reduce air leakage provided joints are properly taped.

Carbon sequestration

Planning authorities often target the reduction of operational carbon emissions through policies such as the Merton Rule[10]. The Stadthaus designers were required to demonstrate how onsite renewable energy technologies would meet 10% of the development's demand. However, they argued that the embodied carbon of the building should be taken into consideration, allowing a dispensation to be made. This was on the grounds that the low embodied carbon of the CLT structure (it was claimed that 188 tonnes of carbon would be sequestered), plus the high levels of energy efficiency and airtightness of the proposed development, outweighed any benefit there would be from installing renewables on an equivalent concrete-framed building with its associated higher embodied carbon.

It should be noted that the topic is contentious and currently the results of embodied carbon assessments vary considerably depending on the dataset and the calculation method used (Box 1). Furthermore, while timber is a material with low embodied carbon, it is a finite resource. It must be responsibly sourced and the volume of timber should not exceed that required to achieve functional requirements.

Box 1 Embodied carbon and carbon sequestration

Embodied carbon describes emissions resulting from extraction and manufacture of construction materials, transport to site and assembly of building components to create a finished building, and emissions from subsequent refurbishment and demolition.

Carbon sequestration is a term used in relation to building products derived from plant materials such as wood, where carbon is absorbed as part of the growing process. The carbon remains 'locked' in the material for at least the lifetime of the building.

Community benefits

Potential advantages for local communities when building on tight, urban sites compared with traditional methods include:

- Less noise because fewer heavy pieces of equipment and power tools are required (and a health and safety benefit for construction workers)
- Quicker construction, so less disruption
- Less waste. Waste timber is minimised through pre-fabrication and dealt with in the factory. KLH claims that at its factory in Austria, waste material that cannot be reused is incinerated in a biomass plant to produce energy for the manufacturing process.

Dry construction

Dry construction meant that dry-lining could be installed directly.

Avoiding weather delays

Because of the high degree of pre-fabrication and quick construction, the programme was less susceptible to inclement weather. KLH states that where storage is required, panels must be stored raised off the ground and carefully wrapped in polythene. Maximum onsite storage is usually two to three days (generally over a weekend).

Smaller substructure

The comparatively low weight of timber superstructure led to smaller, less expensive foundations than might have been expected if a concrete framed building were to be specified. Part of the reason given for the choice of CLT for Bridport House (the second multi-storey CLT housing development in London) was that the building could be constructed cost-effectively over a large Victorian sewer.

2.3 CASPAR II

Project	CASPAR II – City-Centre Apartments for Single People at Affordable Rents
Location	North Street, Leeds LS2 8DA
Dates	September 1999 to June 2000
No. of units	46
Value	£2.4 million
Client	Joseph Rowntree Foundation
Main contractor	Kajima UK
Subcontractor	Volumetric Limited
Architect	Levitt Bernstein Architects
Structural engineer	Alan Conisbee

2.3.1 Summary

The aim of the client, Joseph Rowntree Foundation (JRF), was to prove that it was possible to develop an award-winning apartment block for the private rented sector which could be available for below market rent and still make an attractive return on investment without any subsidy. The scheme was the second in a development programme called CASPAR – City-Centre Apartments for Single People at Affordable Rents.

JRF organised a design competition which emphasised value for money and ease of construction. Architects Levitt Bernstein designed the winning crescent shaped scheme. The contractor, Kajima UK, was closely involved in developing the innovative pre-fabricated approach to construction.

Following completion (Figure 10), the project received critical acclaim and positive feedback from residents, but defects began to emerge which led to a series of investigations into the construction of the building.

Engineers, Arup, produced an unpublished report in mid-2005, which concluded that the flats were at risk of collapse. The tenants were subsequently evacuated. Ultimately in 2006 a settlement was reached between JRF and Kajima whereby Kajima bought the flats from JRF because it was concluded that repair was uneconomic.

Figure 10 CASPAR II shortly after completion

While the proposed method of construction was not inherently problematic, it appears that time pressures played a significant role. CASPAR II demonstrates the importance of tightly controlling construction when dealing with such a complicated kit of parts.

2.3.2 Programme

Construction time was 40 weeks from possession of the site to practical completion (September 1999 to June 2000). The original programme had a construction period of 23 weeks. The main cause of delays was the difficult ground conditions. As a consequence, additional foundations had to be provided and the groundwork programme could not be completed before the arrival of the pre-fabricated units; when these were erected it was difficult to access the building because scaffolding and other materials caused an obstruction. This caused further delays. It was estimated that a comparative development built with traditional methods would take around 14 months.

2.3.3 Construction approach

CASPAR II's semi-volumetric construction

The construction approach developed from the idea that volumetric and panelised construction could be combined to achieve greater efficiencies.

All the complicated, highly serviced parts of an apartment were contained in a single volumetric module. The pod comprised the fitted bathroom, an entrance hall with a heat recovery and water heating system, fitted kitchen, virtually all the electrics and plumbing, installed storage and doors except those leading out onto the balcony. The rest of the flat, comprising the living room and bedroom could be more economically supplied as a series of flat panels.

Each pod was fabricated offsite (Figure 11) and supplied sealed and waterproofed from the factory, complete with internal wall and floor finishes. The system used 89 mm x 38 mm vertical timber studs with a sheathing of bitumen impregnated fibreboard enclosing rigid panel insulation. This type of construction had been previously used in the hotel industry and had the capacity to be self-supporting to five storeys. The panels were also timber framed (Figure 12), with the walls, floors and ceilings made offsite; these components were delivered and then assembled. The pods were craned into place floor-by-floor (Figure 13). The aluminium mono-pitched roof was attached to the top units and sloped from the front (the outer face of the semicircular building) to the rear (the inner face).

Figure 11 Volumetric units were constructed in Cambridgeshire before being transported to Leeds

Figure 12 Timber framed panels were also constructed offsite

The walkways at the front of the building were originally planned to be suspended from steel hangers attached to the roof structure. That was later changed for reasons that shall be explained, so that these walkways were supported by steelwork which had its own separate foundations. Steel ties were retained at various points connecting the roof eaves to the walkways. The walkways were to be slightly sloped so that any rainwater would drain away from the building.

2.3.4 Risks

The project team faced a number of problems when attempting to deliver the building within the agreed programme[11].

Weather

There were some minor delays because of severe weather conditions, including strong winds that caused problems operating the crane. This also caused some damp problems as the timber panels did not have any weather protection. The modules were less affected as they had a protective roof.

Combining pre-fabrication with conventional techniques

The main contractor was unable to agree a price with the volumetric supplier for the external timber rainscreen to be applied in the factory and the design of the balconies and access galleries was not sufficiently advanced for the steelwork simply to be craned into position and suspended from the roof beams. As a consequence the erection of the main timber structure was quick, but the subsequent steelwork subcontract, and the need for a complete scaffold to the inside elevation of the building and partial scaffold to the external elevation to apply the external rainscreen, slowed the contract down in its later stages to the equivalent of a conventional contract.

Combining modular and flat pack techniques

The conclusion of the project team at the time was that the decision to go semi-volumetric was not cost effective, as the challenge of a tight, steeply sloping site, large overhanging roof and semicircular plan combined to exert unmanageable pressure on the flat pack assembly of panels to keep up with the pace of pod delivery.

Some time after occupation, a range of construction-related problems began to emerge which ultimately led to fears of potential catastrophic failure[12].

Differential settlement of the building relative to the structural steel-framed balconies

On 27 September 2000, JRF pointed out to Kajima that there was ponding of water on the walkways. It appeared that the fall across the walkways had been reversed through differential settlement, and water was now standing against the face of the building rather than draining away. This led to the possibility of damage to interiors and building structure. The steel ties between the walkways and the bottom of the eaves were under compression and were bowing.

The explanation provided by the architect and structural engineer was that the access galleries had been originally designed to hang from the roof and that if this had been followed through, the galleries would have settled with the timber frame and the macalloy tie rods would have remained in tension. However, the design of the

Figure 13 The modules were craned into position after the erection of the steel staircases and walkways

access galleries was changed to include a column supporting the galleries from the ground, so that the galleries could be erected at the same time as the pods and be used as permanent scaffolding (although it does not appear that the galleries were actually used for this purpose). The macalloy bars were retained as ties to prevent wind uplift of the roof. The structural engineer stated that tensioners in the ties were omitted due to cost constraints.

Problems with floor construction

Following complaints from tenants about flooring, JRF commissioned an investigation. The surveyor's report dated 7 April 2003 produced a list of issues:

> *'There are severe falls in the floors of the majority of the flats. These are results of large variations in the levels of the floors, and excessive deflection of the floors and misalignment of the supporting trimmers.*
>
> *The floating floor in all the flats appears to be very flexible and this flexibility is due to:*
>
> - *severe falls in the floors*
> - *the chipboard deck is laid parallel with the joist*
> - *the OSB3 structural deck is thinner than recommended and the free edges are not supported*
> - *no herringbone strutting between the joists*
> - *water has entered the construction of the floor causing (dampness) to the acoustic boarding and OSB3 structural deck, neither of which is suitable for use in wet conditions*
> - *door openings are distorted due to poor control of the levels during construction.'*

Incorrectly placed modules

In June 2003, JRF decided that it would commence remedial work on an apartment on the fourth floor to determine the scope and extent of works to be done within the other apartments. During investigations the construction of the rear wall panel was exposed. The flat pack panel had doubled up studs with six studs placed on each side of the door/window opening. The original design drawing showed that the wall panel on this floor should have had single studs doubled up either side of the door/window opening. It appeared that the panel used here was actually intended for use on the ground, first or second floors. For structural reasons, the walls in the flat packs at lower levels should have had more studs than the walls at higher levels. There was concern that weaker construction could have been used lower down in the building.

Wall panel construction

A further problem was discovered during remedial works which related to the strength of the panels fixed to the walls. The type of board used was either plasterboard or OSB. It emerged that spacing of fixings for these panels, and in some instances the board material provided, was not in accordance with the original design calculations and drawings.

Lateral stability and the risk of disproportionate collapse

In the summer of 2005, Kajima asked Arup to consider the issues with the building. Arup reported to Kajima on 13 September, 2005 that there were serious problems relating to the stability and integrity of the CASPAR II building. Arup was concerned about disproportionate collapse. Arup also found that the wind loading was underestimated in the design by about 20%. It was concerned that gas pipe work was not adequately protected. Arup had a real concern that the connection details between the different elements of the building were such that there was 'a key concern for overall stability'. Inadequate provision was made against racking and deficiencies in the construction had, on preliminary calculations, reduced the racking capacity by just over half that which was needed.

Arup concluded: '...current indications do now show that this building cannot safely resist designed wind loads in accordance with current British Standards code of practice and contemporary good practice guidance'.

2.3.5 Rewards

Until construction problems emerged the apartment block proved to be very popular with residents.

Research carried out by Pam Brown Associates in 2001[13] examined residents' views of the experience of living in CASPAR developments in Birmingham and Leeds. Interviews and survey information revealed the following views:

- The survey appeared to support the decision to employ architects who used contemporary award-winning designs. It also confirmed the view that the look and feel of buildings, as well as location, matter to people and affect their decision to move in and then stay.
- Residents were pleased with the design and appearance of both CASPAR developments. They particularly liked interesting features such as the artistic external lighting at Leeds. One hundred per cent of residents questioned were able to recommend living in a CASPAR-type development.
- The design and spaciousness of the apartments was popular. Residents in Leeds particularly appreciated being able to separate the living room for dining in, as a study or space for guests. Space standards were seen to be generous and the developments met Lifetime Homes criteria for accessibility and adaptability (making them suitable for a large proportion of disabled people)[14].
- Noise, often a source of dissatisfaction in some developments, does not appear to have been a concern. The majority of residents were very satisfied with high levels of soundproofing. The survey found that just under three-quarters of those surveyed felt that the sound insulation was good or very good. Residents particularly liked the triple glazing, which gave protection from traffic noise on the nearby major roads.

2.4 Castlefields Estate Regeneration Project

Project	Castlefields Estate Regeneration Project
Location	Castlefields Estate, Runcorn WA7 2SN
Dates	2002 to present
No. of units	Over 800
Value	£90 million
Client	Plus Dane Group
Contractor	Cruden Construction Ltd
Architect	John McCall Architects
Structural engineer	Sutcliffes Structural Engineers
Employer's agent	Tweeds Construction Consultancy
Lean consultants	RWD
Closed panel timber frame system supplier/manufacturer	Space4, Maple

Figure 14 Waterbridge Mews, the first phase of the Castlefields Estate Regeneration Project to trial the closed panel timber frame system

2.4.1 Summary

Through consecutive phases of housing development, the project team optimised the use of a closed panel timber frame system. Measures were developed to deliver improvements in construction speed, better environmental performance, a reduction in construction waste and cost savings. The original Castlefields development was built between 1968 and 1972 as part of Runcorn New Town. The Castlefields Estate Regeneration Project is a key element in a 10-year master plan to replace ageing, deck access flats with new community facilities, transport infrastructure and modern mixed tenure housing.

The various phases of construction have shown an increasingly sophisticated approach to closed panel timber frame construction, but significant programme savings have been difficult to achieve. Site constraints which have nothing to do with the method of construction, such as unplanned statutory authority service diversions, have been a major source of delays.

Many of the problems encountered in the initial phases have been gradually overcome through a process of design evolution and the application of Lean thinking (see page 26 for definition). The closed panel timber frame system has been simplified, with the understanding that pre-fabrication should only be taken so far to maximise value for money and minimise damage to panels onsite, particularly glazing.

Long-term relationships and collaborative working between contractor, client and design team have been essential in transferring lessons learned from one phase of construction to the next. Homes built as part of the latest phase have been largely defect free.

2.4.2 Programme

Following the introduction of efficient construction management techniques, a number of KPIs were introduced by the client, including targets for reducing the construction programme of future phases. The overall contract period overran on some phases due to unplanned statutory authority service diversions and connection delays.

- **Waterbridge Mews:** 13-week overrun (problems in the ground, with site access and the availability of labour).
- **Fitzwilliam Walk and De Lacy Row:** 54 new dwellings, 85-week programme, 9-week overrun.
- **The Butts:** 30 new dwellings, 63-week programme, 11-week overrun.
- **Caesar's Close:** 7-week overrun (the 20 houses were completed ahead of programme, but the flats had to stand idle while a gas main was diverted). If the gas main issues had not arisen then the contractor estimates the project would have completed 6 to 8 weeks early.
- **Kingshead Close:** 63-week contract including 10 weeks of demolition works. The KPI target was to finish 9 weeks early. Demolition took 12 weeks and the project was handed over after a 56-week total build programme. The contractor estimated 7 or 8 weeks more than the 63-week programme required for a traditional build.

2.4.3 Construction approach

Closed panel timber frame

Closed panel construction involves factory pre-fabrication of softwood frames which are backed with a timber sheet material, complete with insulation, vapour barriers and plasterboard fixed to 'close' the panel. Windows, doors, wall sockets and service conduits can also be factory fitted to reduce the amount of work required onsite. Panels can be erected in a matter of hours.

This approach is attractive for a number of reasons: it is typically quicker onsite than traditional construction methods, progress internally is not dependent on installation of external cladding, good tolerances can be achieved so it is possible to achieve a high level of airtightness, pre-fabrication should mean fewer defects and timber is considered to be a sustainable building material when responsibly sourced.

Space4 and Maple supplied the closed panel timber frame systems for the Castlefields Project.

Housing Corporation funding conditions were the incentive for Plus Dane Group to search for a suitable MMC system for the Castlefields Project. The RP was aware of the advantages of timber frame construction through experience of previous developments. The main contractor, Cruden, was relatively inexperienced with this type of construction. Cruden and closed panel timber frame supplier Space4 developed a partnership which was to continue on future phases over several years.

The Waterbridge Mews project (£4.9 million) was the first phase of development to trial a closed panel timber frame system. The Space4 system was used on continuous flight auger piles. The system was selected after planning so supplier input into the design was limited. However, according to Cruden, all panels were in place 12 weeks after the ground floor slab was completed and the site was dry in a further nine weeks, 25% quicker than usual. Windows and doors were factory fitted to wall panels and delivered to the site along with floor cassettes, packaged according to house type. Panels were erected onsite and finished with a combination of brick, render and western red cedar.

Plus Dane Group employed Lean consultants, RWD, to help the team develop working methods and procedures to improve the efficiency of site processes. RWD monitored the conclusion of the Waterbridge Mews and Rowlands Walk phases in 2005 in order to understand the methods being adopted by Cruden. The team met at various stages during 2006 while demolition works were being undertaken and in June 2006 a set of targets for future projects was discussed and agreed. These targets related specifically to the programme, snagging and waste minimisation. Maple then replaced Space4 as the timber frame supplier. Lean construction methods have continued to be used on phases completed during 2006 to 2009 and will be used on the remaining phases.

Both design and processes have evolved to improve construction speed and quality as the development has progressed.

2.4.4 Risks

Programme delays following completion of the superstructure

Although installation of the closed timber panels at Waterbridge Mews was quick, delays were incurred with follow-on trades. Firstly, access to the site was constrained to one entrance so access to subcontractors other than Space4 was restricted to prevent congestion. This meant that work did not overlap as it could have, so potential time savings could not be exploited. Secondly, and critically, there was a significant shortage of labour to deliver follow-on work. Recent phases have not suffered from the same labour shortages.

Capacity of the closed panel timber frame system to adapt

With a major development of this size, delivered through multiple phases over a number of years, there was a need to adapt the closed panel timber frame system to accommodate design changes and different floor plan types. This posed detailing problems which contributed to the change of supplier.

Plus Dane Group found that an adaptable product was not easy to find for a reasonable price in the market. Closed panel timber frame production was found to have high unit costs for the small suppliers approached, and large suppliers were risk averse and so reluctant to change their products and processes to comply with the more demanding levels of the Code for Sustainable Homes (CSH). However, at the time of writing, Plus Dane was working with Maple on a CSH Code Level 5 unit and on an approach to attain CSH Code Level 6.

Unforeseen site constraints

Regardless of the programme benefits of using the closed panel timber frame system, significant delays occurred through unplanned statutory authority service diversions, connection delays and because substations in buildings had to be retained and worked around.

Unnecessary pre-fabrication

At Waterbridge Mews, construction began with windows being installed in the factory, but reverted to onsite installation at a later stage. This was because panels did not stack efficiently on the delivery vehicles and because it was difficult preventing windows from getting damaged/dripped on once onsite.

Over-complex detailing

Waterbridge Mews had a large palette of materials. This increased the number of details which complicated construction and was addressed in later phases. Western red cedar cladding was omitted from the later phases of development at the Castlefields Project.

Project team changes

Efforts have been made to retain the whole project team where possible, to ensure lessons were learned for future phases. The same demolition contractor was used who was able to quickly find and remove asbestos; the same architectural staff were involved over a period of five years and the same subcontractors (mechanical and electrical [M & E], plasterers, steelwork, and ground works). One lesson learned through the Lean process was that 'throwing labour at the job' was not the answer for this type of repetitive, unusual work – better to employ the same operatives to do the same work each time.

Traditional contractor frameworks

The team learned through experience to design with the system in mind. This involved collaborating from a very early stage. Waterbridge Mews was designed without Cruden or Space4 being involved. With the King's Head Close project, even the M & E contractors came to the concept meetings.

Plus Dane felt that traditional frameworks did not encourage this kind of working.

2.4.5 Rewards

The closed panel timber frame system was well liked by the contractor. Particular benefits were identified:

- During spells of very bad weather, including the snow of 2008/9, progress was maintained. The timber frame solution meant interiors were progressed with brick reprogrammed for a later date.
- Cruden believed this form of construction offered a truer structure than traditional masonry with the result that trades found it easier and quicker to work with kitchen fitters for example.
- Cruden drew a comparison with wet-plastered traditional masonry where an interior can be very damp when joinery commences which can lead to warping of architraves and skirtings. This has not been a concern at Castlefields.

Three other key factors have contributed to programme efficiencies as follows.

The application of Lean thinking

Lean is a term used to describe an approach to construction which targets improved efficiency and reduced waste while preserving quality. Lean methods often involve challenging traditional ways of doing things.

A range of improvements to the design and construction process emerged. For example, at Waterbridge Mews, temporary access stairs were provided to upper storeys during construction to allow internal work to advance. However, these were heavily used and proved to be restrictive, slowing progress. On later phases, robust, simply-supported permanent galvanised steel staircases were installed at an early stage to allow speedy, generous access (Figure 15).

Cranes for erecting timber panels for the latest Kingshead scheme were also used to lift air source heat pumps into place (Figure 16).

Quality sign-off was carried out at each stage rather than addressing all defects at the end of a project. No defects were recorded with the scheme that was completed last. After initial reservations, Cruden's site manager became fully committed to the Lean process.

An Innovator of the Month scheme ensured that all staff had the opportunity to contribute, supported by chairman's lunches that were used to demonstrate that there was no hierarchy for the generation of ideas. Another scheme, Innovation Circles, brought together the supply chain in an open approach to sharing ideas and tackling problems.

The ongoing relationship between client, contractor and design team

If a 10-week time saving is identified through team working, the cost benefit is shared. The Lean consultants, RWD, were initially paid by Plus Dane, but Cruden agreed to joint fund RWD on later phases having seen the benefit of this arrangement.

The experience gained over consecutive phases of construction

Changes to specification were possible with a better understanding of what the systems offered. The Maple closed panel timber frame units had sealed tongue and groove joints rather than butt joints which made it easier to make the buildings airtight. Air permeability values achieved on the latest scheme vary from 3 to 5 $m^3/m^2.h$.

The current system uses 90 mm studs and 140 mm polyurethane blown foam insulation to achieve a U-value of 0.16 W/m^2K. A supplier who can offer triple glazed windows with a U-value of 0.7 W/m^2K was being considered.

Plus Dane undertakes regular post-occupancy evaluations of completed schemes to understand what can be improved.

Figure 15 Robust, permanent staircases were installed in place of temporary access to speed up construction

Figure 16 Closed panel timber frame units and air source heat pumps were unloaded onsite and craned into place

2.5 Lime Tree Square

Project	Lime Tree Square
Location	Street, Somerset BA16 0FX
Dates	Planning reserved matters in 2007; construction start date September 2007; completion date October 2008
Size	138 homes at the southern end of the site including 30 homes for social rent
No. of units	138
Value	£35 million total; £2.2 million for the 30 affordable housing units
Client	Crest Nicholson
Landowner	C and J Clark International Ltd (Clarks Shoes)
Developer	Crest Nicholson (Knightstone as registered social landlord for the affordable housing)
Architect	Feilden Clegg Bradley Studios and CMS Bath
Structural engineer	Arup and Gary Gabriel Associates
Planning consultant	Alder King
SIPs supplier	Kingspan TEK

Figure 17 Terraced homes at Lime Tree Square (© Crest Nicholson)

2.5.1 Summary

Lime Tree Square was the first phase of a 400 unit masterplan for a new urban quarter for Street in Somerset, which is now complete and fully occupied (Figure 17). The scheme has won several awards (including a CABE Building for Life Gold Standard and Award) and is intended to be a national exemplar of sustainable living and a model for urban development in semi-rural towns. The development comprises one and two bed apartments within four storey buildings. These are mixed with two, three, and four bedroom 'deck houses' which have high external terraces. Crest Nicholson, the scheme's developer, chose a structural insulated panel (SIP) system primarily for the environmental benefits this could offer.

The design of the dwellings varies considerably both in terms of the floor plan and external finishes. The project required 'hands-on' involvement from the developer throughout to resolve a series of design and detailing challenges.

The completed scheme has been an award-winning success. Speed of construction was not the primary driver for the selection of SIPs and a number of factors intervened to prevent the construction process from achieving its potential. The key reason was the large palette of materials and the number of bespoke details to be resolved during construction. The project highlights that in the absence of a complete set of typical construction details there is value in front-loading the process by spending more time resolving details and planning the build to minimise construction time onsite.

2.5.2 Programme

Construction took 13 months. The developer's view was that this was not any quicker than a traditional masonry build would have taken – although in this case, speed was not the most important objective.

2.5.3 Construction approach

Structural insulated panel systems

SIPs form part of a pre-engineered building system, manufactured offsite in a controlled environment and then transported to the site for erection.

Typical composition of panels involves sandwiching a high performance insulation core between two layers of Oriented Strand Board type 3 (OSB/3). During manufacture, the insulation can be bonded to the OSB/3 facings. These materials act together to create a structural composite offering stiffness, strength and predictable responses to applied loads. Panel widths typically range from around 200 mm to a maximum of 1220 mm, and can be produced in lengths up to 7500 mm.

The loadbearing properties of SIPs are usually exploited with panels used for the inner leaf of buildings up to four-storeys high. Panels can be finished with a variety of conventional materials, or they can be used to construct pitched roofs or infill panels in steel or timber structures.

Advantages claimed include: increased speed of construction since panels arrive onsite ready for erection; high levels of thermal insulation with U-values down to around 0.10 W/m^2K; minimal construction waste as panels are manufactured offsite; earlier start for other trades because a weathertight envelope can be achieved before finishes are applied; and high levels of airtightness, provided panels are joined correctly.

Architects Feilden Clegg Bradley Studios led the design team which produced the master plan and concept design for the buildings. Crest Nicholson's project team working with SIPs supplier Kingspan TEK were responsible for delivering the scheme. Alternative timber frame construction approaches were considered, but Crest Nicholson negotiated with Kingspan TEK until acceptable costs were agreed. Kingspan TEK was also contracted to build the internal non-loadbearing walls for the sake of simplicity and a clean commercial arrangement.

2.5.4 Risks

Design effort required to achieve Building Regulations compliance

The project received a lot of attention from Building Control because of the innovative approach, in particular, the single skin construction, the mechanical ventilation with heat recovery system (MVHR) and the roof terraces.

Part B – Fire Safety
One of the features of the scheme is the use of external decking accessible from upper floors which provides additional amenity space for residents. The initial design intent was to use timber cladding on walls enclosing these roof terraces. Given the possibility that residents might light barbecues, concerns were raised over the perceived risk of fire spread. A render system was used instead with additional fire protection behind the finish.

Part M – Access to and Use of Buildings
Level entrance thresholds were a design requirement which posed a design challenge. Sole plates for the TEK system were just above the damp proof course level and there was a concern that level access might expose SIPs to standing water at the entrances. A new detail was developed which allowed water to drain to points away from the thresholds.

Product development time

The supplier was in a state of change and Crest Nicholson's project manager estimated that standard details for the Kingspan TEK system took one and a half years to emerge. Therefore Crest Nicholson was working with the system for some time before these could be incorporated.

Managing tolerances

The system required a tolerance at the sole plate of no more that 15 mm over 5 m. Building to this tolerance proved to be challenging and where gaps exceeded 15 mm, sealing the buildings was difficult, but good levels of airtightness were ultimately achieved.

Disjointed construction programme

The client's view was that although a faster rate of build could have been achieved, the construction process was fragmented. For example, the SIPs contractors arrived to install the sole plates, left the site then returned to erect the panels over a two-week period. After erecting the panels they left the site again before returning to continue work. While panel erection was swift, technical issues intervened to slow progress.

Building services integration

Distribution of MVHR ductwork needed to be redesigned a number of times in order to suit the structure. Parallel beams in joist zones could not be trimmed, so the design had to accommodate this constraint.

Design variation

Every house type had to be considered. Due to the variety of different designs the client had to be heavily involved with detailed design issues. Fewer, simpler designs would have allowed the contractor to progress independently and more quickly. Over 100 standard details were eventually needed.

Large palette of materials complicated detailing

Junctions between render and cedar cladding were complex with single skin construction. As there were different wall build-ups, external finishes stepped in and out. A bespoke drip detail was required to address the risk of staining (Figure 18).

Figure 18 Junctions between finishes required bespoke detailing (© Crest Nicholson)

Scaffolding

Scaffolding needed to be adjusted several times. After erection of the wall panels, scaffolding was dropped to first floor level then raised again when the roof was installed before being dropped again for the cedar cladding. Scaffold levels for the SIPs were different from levels required by other trades.

Similar issues have been identified in the Design for Manufacture projects[15]. The Renny Lodge and Linton schemes produced by the SixtyK consortium (Crest Nicholson) were also constructed using Kingspan TEK.

At Renny Lodge it is worth noting that the speed of construction was compromised by the complexity of the design and the incorporation of some traditional masonry construction and inclusion of a roof lantern which was not pre-fabricated. Fitting the lantern required multiple trade visits, reducing time and cost efficiencies.

At Linton, materials were generally delivered on time and erected promptly, although overall speed may have been affected through the use of different architects at different stages. This scheme also used the roof lantern design.

2.5.5 Rewards

Thermal performance

The primary driver behind selecting SIPs was its thermal performance and environmental credentials rather than speed of construction. A U-Value of 0.21 W/m^2K for walls was targeted and achieved.

A target figure of 4 $m^3/m^2.h$ was set and for the most part achieved. The client reported that only one house failed a pressure test and this was because of detailing around a soil vent pipe.

Cost

Timber frame construction was considered at one stage. Using the findings from cost analysis, the client was able to bring pressure to bear on the TEK supplier. The supplier was able to meet cost requirements.

Defects

Few defects were recorded. Shrinkage was within expected limits (2 to 3 mm per storey). Occupant feedback was generally positive and the client was pleased with the outcome.

2.6 Bourbon Lane

Project	Bourbon Lane
Location	Bourbon Lane, White City, London W12 8AQ
Dates	Started June 2005, completed July 2007. All tenants moved into the development over a four-week period. Tenants were invited to inspect each apartment before handover to ensure snags were addressed to their satisfaction
Size	6900 m^2
No. of units	78 affordable homes
Value	£11,714,000, equivalent to £1707 per m^2
Client	Octavia Housing and Care (now Octavia Housing)
Main contractor	Como Homes
Subcontractor	Nordicon light gauge steel panels (by Ruukki) were installed by Prater
Architect	Cartwright Pickard Architects in partnership with French practice B+C Architectes
Structural engineer	Campbell Reith
Mechanical engineer	Atelier Ten
Steelwork contractor	Billington Structures Ltd

Figure 19 The steel frame was designed to allow the upper floors to cantilever over the access road, increasing plot density

Figure 20 The residential blocks abut Westfield shopping centre in west London

2.6.1 Summary

This award winning project was the result of an Anglo-French design competition supported by CABE. The aim was to demonstrate best practice and new thinking in affordable housing. The winners were Cartwright Pickard Architects in partnership with French practice B+C Architectes.

The site is unusual in that the buildings abut the Westfield shopping centre in west London and at the same time the site adjoins a well-established residential community of terraced houses (Figures 19 and 20). The scheme provides entirely double-aspect dwellings. Government encouragement of MMC approaches and difficult access to the site both prompted the client, Octavia Housing and Care, to consider an innovative steel-framed solution that could be rapidly constructed. Although high densities have been achieved, each dwelling has a garden, a generous roof terrace or a balcony.

Unusually on this site, a competition allowed the client to compare different methodologies. The selected approach was chosen for a variety of reasons, including the quality of the design, Government encouragement for MMC-based solutions, the benefits a steel frame could offer in terms of increasing site density, and the suitability of the approach given the restricted access to the site. The cladding system was undoubtedly quick to install, but the overall programme did not benefit significantly given the comparatively slow progress of the more conventional aspects of the scheme.

2.6.2 Programme

Extensive remediation of the site was required before construction could begin. Also, since the light gauge steel external wall solution depended on prior construction of the primary steel frame, the speed advantages of a purely panelised approach could not be realised. Furthermore, issues with the sequencing of construction and achieving water tightness slowed construction to that of a conventional build.

2.6.3 Construction approach

Light gauge steel frame

Light gauge steel sections (also known as cold-formed steel sections) are formed by cold rolling thin steel sheet into shape. Thin steel sheet is typically 0.4 mm to 3.0 mm thick and pre-galvanised, such as with a zinc coating, for corrosion prevention. Light gauge steel sections and components can be assembled offsite in factory conditions to create transportable sub-assembly panels for delivery and installation onsite. Systems can be either loadbearing, eliminating the need for a primary steel or concrete structure, or non-loadbearing and used as infill panels or external wall elements. Light gauge steel construction can share many of the benefits of other types of panelised construction including reduced time onsite.

With the exception of a block of three-storey timber framed terraced houses, the buildings are steel framed. Both timber and precast concrete were considered for the whole scheme at the feasibility stage, but a steel frame was preferred since this enabled the very distinctive 6 m cantilevered sections (Figure 21). These were achieved using storey-high Vierendeel girders fabricated from 254 mm columns. 203 mm steel beams and columns make up the rest of the structural frame. Downstands are avoided by using 150 mm precast hollow core floor slabs with 50 mm in-situ structural topping. The design was awarded a commendation at the Structural Steel Design Awards 2008.

Over 5000 m^2 of Nordicon light gauge steel wall elements were installed onto the steel frame. The panels are non-loadbearing and can be installed quickly, reducing construction time. They can be pre-cut to accommodate features such as wall penetrations, difficult corners and balconies. The wall elements were installed by cladding subcontractor Prater who worked with the manufacturer, Ruukki, to adapt the system to the precise requirements of the project.

Figure 21 The cantilevered steel frame (© Tata Steel)

Figure 22 Wall panels arrived complete with windows (© Tata Steel)

The wall panels were made offsite in Estonia, complete with external windows and doors, insulation, and an internal layer of plasterboard (Figure 22). The system was designed around a framework of thermally broken steel purlins and panels were available in a wide range of sizes, typically 3 m x 8 m. Less secondary steelwork was required because of the long spans.

The panels arrived in sealed packs and were hoisted up and fixed to the structural frame by Prater's operatives to make the interior watertight. Prater then fixed Siberian larch rainscreen cladding using cherry pickers. Cementitious rainscreen cladding panels were used to add colour. Other cladding options include flat steel, aluminium sheets, wood, bricks, glass, render, as well as stone or ceramic tiles.

The offsite solution was primarily chosen to help minimise onsite construction and deliveries in this heavily congested area and to ensure a highly consistent build quality.

2.6.4 Risks

Construction detailing

One of the difficulties of this approach is resolving fire and acoustics issues. Fire protection in particular requires careful detailing and a systematic approach to problem solving. One of the downsides for designers is that the lessons learned by design teams on previous projects are not passed on. More widespread sharing of detailing and specification knowledge would benefit the industry, particularly for architects and engineers. As is the case with many MMC systems, time savings onsite can only be achieved if problems are resolved pre-construction. If the lead in time is excessive because detailing takes a long time to be resolved, the whole project programme can suffer.

Lack of construction experience

The main contractor, Como Homes, was inexperienced in this form of construction. Lessons about when and how to provide protection to avoid damage to panels were learned on the job rather than in advance. Issues with the sequencing of construction and achieving water tightness slowed progress.

Site remediation

Considerable time and money went into remediating the site which was originally the location of a large exhibition building constructed for the 1908 Summer Olympics; at an estimated cost of £1 million. This was a risk that was only partially understood at the start of the project.

Achieving planning permission

The design was unusual but risks associated with the planning application were managed by involving the planning authority early and consulting extensively with the local community.

CABE stated in *Winning House Designs: Lessons from an Anglo-French Housing Initiative* that 'The housing association did not yet know the identities of the prospective tenants, so held a series of meetings with people from local tenant forums, including the Hammersmith & Fulham tenant representative group, to get their response to the design'[16].

Also, given the site's location, immediately adjacent to the Westfield shopping centre (Figure 20), the design team was also able to argue that the aesthetics and the scale of proposals were appropriate.

Defects

Internal rainwater downpipes, which were intended to ensure low maintenance, dropped, thereby creating internal leaks. The colourful cementitious panels cracked at the corners where they were nailed. The view was that the panels were nailed too close to the corners and where differential movement occurred the panels cracked at the weakest points.

2.6.5 Rewards

Scaffolding-free installation

Because the pre-fabricated panels eliminated the need for scaffolding, savings of £350,000 were realised. Octavia Housing and Care used the savings to invest in a combined heat and power plant. As a result, not only have the environmental impacts of the development been reduced, but energy bills are reputedly very low.

Scaffolding-free installation of the external walls and windows provided a reduced risk to the health and safety of operatives – fewer operatives were required to work at height for less time than a traditional build.

Higher density construction

The steel framed structural approach enabled large cantilevers to be used and therefore a higher density of tenant accommodation could be provided on the site for Octavia Housing and Care. The competition brief demanded a minimum number of 45 units. The architects successfully demonstrated that 78 units, at a density of 282 habitable rooms per hectare, could be provided. Other structural approaches were considered including options using concrete, but only steel allowed the cantilevers to be used (Figure 19).

Suitability for tight construction sites

Access to the site was constricted with limited space for storage. Just-in-time delivery of components made construction easier, lowering the costs of site management and storage facilities. This should have led to fewer trades being involved and less waste generated onsite, although data has not been found to support this.

Reduced impact on the local community

The site is set within an existing residential area. Offsite construction of wall panels ensured that construction of the envelope could proceed quickly and that disturbance and annoyance for neighbours was minimised.

Positive occupant feedback

Resident feedback to Octavia Housing and Care was very positive – other than the minor issues highlighted, no major defects were raised with the architects.

2.7 Oxley Woods

Project	Oxley Woods
Location	Oxley Woods, MK4 4HS
Dates	The Design for Manufacture competition was launched in April 2005. Construction is ongoing with the majority of the site built out
Size	3.26 ha site
No. of units	145. These range from a 62.5 m^2 two-bedroom house to four-bedroom houses of 150 m^2. The brief required 56 homes to be constructed for £60,000, including 43 affordable homes
Value	£13 million
Consortium leader	Taylor Wimpey
Subcontractor	Wood Newton
Architect	Rogers Stirk Harbour + Partners
Project managers	Anser Project Managers
Engineer	Woods Hardwick
Sustainability consultant	Rybka
Landscape design	Gillespies
EcoHat manufacturers	Nuaire

Figures 23 and 24 Completed homes at Oxley Woods

2.7.1 Summary

Oxley Woods, near Milton Keynes, is one of the sites developed as a result of the Design for Manufacture competition. The competition challenged the construction industry to build high-quality sustainable homes to a construction cost of £60,000 or £784 per m^2. The contest was launched by the Government in April 2005 and was run by English Partnerships (now part of the Homes and Communities Agency). After several stages of selection, the winning consortia for six sites were encouraged to develop construction efficiencies by working collaboratively with all the key players in the supply chain in order to maximise the potential quality and environmental performance of new homes. More details on the Design for Manufacture competition can be found in the competition publication *Design for Manufacture – Lessons Learnt 2*[15].

George Wimpey South Midlands (now Taylor Wimpey plc) was selected as preferred developer for the Oxley Woods site, with Rogers Stirk Harbour + Partners as architects.

Many aspects of the development have been a success. Testing a prototype provided valuable lessons for improving construction speed. Combining panelised wall construction with roof cassettes and a single-ply roof finish has enabled houses to be made weathertight quickly. Scaffold-free construction has also improved speed of assembly. Offsite assembly of the EcoHat roof lanterns removed construction complexity from the site and made programming more predictable. Defects emerged in the first houses constructed, although these appear to have been rectified and more recent homes have not exhibited the same problems.

Despite programme efficiencies, the developer proposed adopting a more traditional approach to the design and construction of the final 29 homes at Oxley Woods.

2.7.2 Programme

A prototype dwelling was constructed at Wood Newton's factory which allowed construction techniques and specification to be refined. BRE's CaliBRE tool was used to monitor activities onsite. Erection of timber frame and roof carcass averaged at 95 and 110 man-hours per plot. The cladding system, installed using scissor lifts and cherry pickers, took an average of 140 man-hours to install for a 76.5 m^2 house, in comparison to a brickwork skin built from scaffolding which takes in the range of 210 to 300 man-hours for a house of the same floor area. Return visits were required by the cladding contractor to avoid damage to lower cladding panels.

All houses were treated as detached, even those in a terrace, resulting in design and time savings. Total construction time per dwelling is about half that of a conventional build.

2.7.3 Construction approach

Wood Newton closed panel timber frame: external walls and party walls

The system was a form of closed panel timber frame system, manufactured offsite at Wood Newton's Derbyshire factory complete with window and door cut-outs (Figure 25). The panels form the external and internal walls. No other structure is required. Closed panels typically incorporate insulation at the manufacturing stage but here the panels were insulated onsite with blown Warmcel insulation (made from recycled newspaper) after erection and once the building was watertight, filling the 145 mm cavity. Wood Newton was able to produce very long and stiff panels to tight tolerances, which allowed the firm to develop business in the retail and education sectors and to supply products to the sporting venues for the London Olympics. At Oxley Woods, multi-storey panels were used to speed up and simplify construction and allow for continuity of insulation and waterproofing at junctions with intermediate floors. Once erected, the system can accept a variety of different types of rainscreen cladding – Trespa has been used at Oxley Woods. This is a non-porous board formed from recycled softwood, available in a variety of colours.

Figure 25 Wood Newton's manufacturing facility

Roof

The panelised system also included timber roof cassettes. Once installed, the cassettes provided a degree of weather protection during construction. A vapour check barrier was added and a single layer of 100 mm foil-backed EcoTherm polyurethane foam core fixed above. The warm roof design reduced the risk of condensation and timber rot. The void left between timber members was used for services distribution and lighting installation. The roofing contractor then mechanically fastened a single-ply PVC membrane (supplied in three shades of red) to the roof board. Seams were welded. It was possible to make the plot weathertight in 1.5 days.

Windows

The timber-framed windows are double-glazed with low-emissivity glass.

The final stage competition submission allowed for both a Metek Building Systems (light gauge steel frame) and a timber frame system. The Wood Newton timber frame solution was preferred. Constructing a prototype offered valuable lessons: panel sizes were increased from single storey to full height (up to three storeys) improving construction efficiency which enabled the roof to be in place on day two of the build. Rogers Stirk Harbour + Partners was also able to confirm that Trespa rainscreen cladding would be specified.

Once construction commenced, lorries delivered panels directly from the Wood Newton factory loaded in the right order for assembly on arrival. Lorries remained onsite providing weather protection to panels until these were unloaded. Wall panels were erected first, followed by floors and roof cassettes. These were assembled using a mobile crane without the need for scaffolding, except for a temporary parapet rail during roof construction (Figure 26).

Some of the properties were constructed with an EcoHat. The EcoHat contains a solar thermal panel system and a ventilation fan. The panel pre-warms supply air and preheats domestic hot water. The fan actively ventilates the house and filters out pollen. The EcoHats were manufactured offsite by specialist supplier Nuaire, ensuring a good level of quality and reduced impacts on construction programming, although where Ecohats were specified, achieving weather tightness depended on timely delivery and installation.

Rapid, dry construction techniques were employed internally too: tiling has been avoided through specification of glass splashbacks in the kitchen and showerproof panelling in the bathroom.

Figure 26 The latest homes under construction. The timber superstructure and roof are assembled without scaffolding

2.7.4 Risks

Lack of manufacturer track record

Initially, English Partnerships had some reservations about system manufacturer Wood Newton. The company was not a well-known name in house building at the time, although had a good reputation as a specialist joinery contractor. It operated out of relatively small premises and the manufacturing process involved only limited automation. Letters from the bank confirmed the company's viability and the high quality of product that was demonstrated at the prototype stage provided confidence.

Certification, suitability and insurability

One of the performance aspects assessed through the Design for Manufacture competition was innovation risk management: 'Measures for testing new products and processes through an innovation and risk management protocol.'[15]

While many MMC systems are accredited and certified, this was not the case with the Wood Newton closed panel timber frame system at the outset of the project. A strategy was needed to ensure that appropriate accreditation was achieved. Taylor Wimpey established close links with insurers, mortgage lenders and NHBC to address confidence issues. This resulted in NHBC and Council of Mortgage Lenders' approval.

We understand that initially some residents experienced difficulties securing insurance from mainstream organisations because the non-standard type of construction was not recognised, but that recently this has proved to be more straightforward.

Cost control

One of the well-recognised risks associated with new MMC systems is the uncertainty about the overall cost of the systems compared to traditional construction approaches. Costs have been higher than predicted at Oxley Woods. It is the most expensive of all the Design for Manufacture sites. The Design for Manufacture *Lessons Learnt* report[15] highlights that the construction cost of a two-bedroom house was £81,390 which compares with a bid price of £56,745. Most of this uplift was due to higher than expected superstructure costs. The cost for the superstructure of a two-bedroom unit was £54,621 against a bid price of £23,661. A number of reasons for this discrepancy have been suggested: the number of different types of design required was greater than expected, partly because the non-linear arrangement of houses meant building façades had to be stepped, and because of Manufacture by Design requirements relating to window openings in flank walls. Construction inflation also played a part – the cost of Trespa cladding increased 25%. Arguably, none of these factors would have had as much influence on a more traditional, slower construction approach.

Defects

The site won the 2007 Taylor Wimpey (South Midlands) Excellence Award for the quality of the houses. However, a number of problems emerged with the first houses built. Resident complaints about water ingress and cracked glazing prompted extensive investigations involving the drilling of inspection holes around window openings and the temporary removal and replacement of large areas of Trespa cladding. Windows and doors were replaced and future houses featured different window types. Building-out the site has been a learning process and the problems associated with the first houses have not emerged in the later phases of construction.

Public perception

The use of Trespa cladding (more commonly associated with commercial and industrial developments) and the strong architectural forms are defining characteristics of the scheme. The risk that the unusual appearance of the dwellings would dissuade buyers was countered by educating the marketing team onsite to promote the benefits of the construction method and the ethos of the Design for Manufacture competition. However, demand for the properties has not met expectations. Significantly, Taylor Wimpey announced in January 2011 that the remaining 29 homes of the 145 would be of a different, more traditional construction designed by another architect. The reasons given were that the cost of housing formed of pre-fabricated components had become expensive in the current economic climate and that a steady flow of sales could not be predicted.

2.7.5 Rewards

The kit of parts approach adopted at Oxley Woods facilitated rapid construction. The approach offered a range of benefits:

- Residents have expressed satisfaction with their homes, community and the ethos of the scheme. The recent proposals to complete the development with more traditional house types have upset some residents who want Taylor Wimpey to maintain the spirit of the original scheme.
- The houses were set tough standards of thermal insulation and airtightness at the outset and they appear to be performing well. Thermal imaging[17] demonstrates that common weaknesses at wall/floor and wall/roof junctions have been successfully avoided.
- Health and safety benefits have been achieved through using panelised construction and the subsequent elimination of scaffolding. Just-in-time delivery of panels on Wood Newton vehicles has led to a tidier site and a reduced requirement for plant/equipment.
- Improvements in construction techniques were made possible by collaborative working and a willingness to learn from earlier phases of construction.
- The high quality of finish and low tolerances were achieved through precise offsite manufacturing.
- The scheme has won a number of awards including the Manser Medal for Houses and Housing Award 2008 and the Building for Life 2008 Gold Standard.

2.8 Park Central

Project	Park Central
Location	Lee Bank estate at Attwood Green, Birmingham B15 2EY
Dates	Work began in 2001 and is estimated to end in 2014
Size	20.75 hectare development site, total number of homes by 2106, 13% being available for social rent. Five blocks built using Structherm
Value	Gross public and private sector investment is £350 million
Landowner partners	Optima Community Association, Birmingham City Council
Developer	Crest Nicholson
Architect	Gardner Stewart Architects
Structural precast system	Structherm

Figure 27 Block 78 at Park Central (Photo © Elliott Brown)

2.8.1 Summary

Park Central is a mixed use, mixed tenure development located in central Birmingham in an area that was once a failing housing estate where properties were difficult to let. The site has been subject to major regeneration, and the resulting transformation has achieved the CABE Gold Standard and Award. The bulk of the investment has come through an innovative financial mechanism linked to a development agreement for the upfront provision of £28m of Guaranteed Essential Works in lieu of a land payment and S106 agreement. Developer Crest Nicholson has specified the Structherm Fastbuild precast concrete panel system for five apartment blocks on the site (Blocks 41, 51, 55, 71 and 78), attracted by benefits including speed of construction.

The form of construction has proved to be low-risk in terms of overall ease of construction, achieving regulatory approvals and site handling safety.

Resolving technical issues have sometimes caused delay. Managing tolerances at junctions and openings has been a consistent issue, although not a significant problem.

From a commercial perspective, the attractiveness of a potentially faster precast system approach has been dependent on a number of factors; in particular, the comparative cost of alternative construction methods such as steel frame, and the appetite of the private housing market for new apartments.

2.8.2 Programme

Structherm suggested construction times can be cut by an average of 40% compared with traditional methods of construction. Programme savings of this order have not been seen at Park Central although the opportunity to refine the approach over a succession of projects has allowed incremental improvements:

Block 41	Fastbuild walls, floors, staircases, lift shafts and roof
Block 51	Fastbuild walls, floors, staircases and lift shafts
Block 55	Fastbuild walls, floors, staircases, lift shafts and roof
Block 71	Fastbuild walls, floors, staircases, lift shafts, roof and insulated render
Block 78	Fastbuild walls, floors, staircases, lift shafts, roof and insulated render.

2.8.3 Construction approach

Structherm Fastbuild precast concrete panel system

Structherm designed and fabricated the system based on the architect's concept design.

Several formats were offered, including standard panel, window panel, party wall and long (bespoke) panel. Window and door openings were formed with variable width lintels and spandrel panels or were cast as openings in a one-piece window panel. For the standard system, the modular, storey-height, structural wall panels and window spandrel panels were located and fixed to galvanised steel base channels at each floor level (Figure 28).

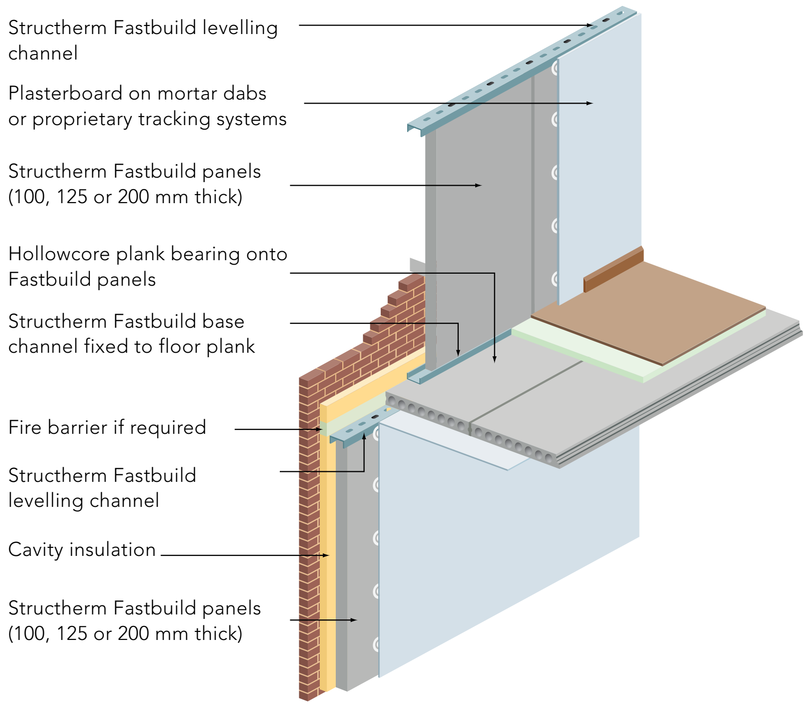

Figure 28 Precast concrete panel and floor slab detail

The wall panels were temporarily braced during this procedure and lintels set in place. Wall panels and lintels were then permanently linked together with galvanised steel capping channels and fixing brackets.

Perimeter walls are loadbearing

Internal walls provided lateral stability to the perimeter walls in the form of fully spanning crosswalls.

The internal walls could also provide support for the floors and roof structure.

In all variants of the system, levelling channels were fixed across the top of wall panels and lintels to provide a level surface for the location of floor and roof members. The pre-fabricated panels formed a quickly erected basic shell. The manufacturer suggested that a dry building shell of up to six-storeys could be completed without compromising other trades.

At Park Central, the architect's design was translated into a Structherm Fastbuild format and supplied as a dry shell package for construction by approved contractors (Figure 29). Panels were numbered to simplify construction.

For the most part, the external walls are brick clad with an insulated cavity. An external insulated render system was also used extensively. Loadbearing precast units have been used for the party walls and metal stud for internal non-loadbearing walls. Both precast concrete floors and composite concrete floors have been used; the precast floors proved to be simpler and achieved better tolerances.

Figure 29 Completed residential block at Park Central (© Elliot Brown)

2.8.4 Risks

Assessing cost effectiveness

Cost effectiveness for Crest Nicholson on projects such as this depends on several factors but most importantly the comparative price of a steel-framed structure and whether completing quickly is important for the purposes of achieving swift sales (thus justifying the additional cost). The price of steel was sufficiently high at the time of procurement to justify the precast approach. However, the current depressed state of the residential market means that the benefits of a reduced construction programme are not a major driver at the moment.

Managing tolerances

The advantages precast units offer over traditional masonry in terms of speed and simplicity have to be weighed against the challenge that a single large unit presents in terms of construction tolerances. While panels can be manufactured to a high degree of accuracy, they offer no leeway when it comes to joints. The feedback from the Park Central development was that window openings posed some difficulties: some panels settled a little, throwing out tolerances. Some windows needed adjustment, occasionally by physically modifying dimensions. If working to 10 mm tolerances is important, this is asking a lot of a precast system.

Managing steelwork fire-protection

Since the Ronan Point[18] disaster, designing-out the risk of disproportionate collapse has been an essential requirement of the approval process and is particularly significant for multi-storey precast concrete structures. Structherm's solution involves additional steelwork. In order to ensure integrity, this steelwork required fire protection. The challenge was to understand what steelwork needed to be fire protected and ensuring that this was undertaken before the steelwork was covered up to avoid delays caused by opening-up.

Achieving sustainability objectives

There are a number of environmental benefits that can be exploited with precast construction such as its high thermal mass, but there are also disadvantages to consider. Most significantly, in relation to the materials section of the CSH, the material has some drawbacks when compared to alternatives such as timber. The CSH references *The Green Guide to Specification*[19]. Variants on precast concrete internal and external walls do not score highly. The few precast cladding solutions included in the *The Green Guide to Specification* are rated between B and D. For projects where higher Levels of the CSH are an objective, design teams are required to work harder to achieve credits in other parts of the assessment.

Managing subcontractor interfaces

The developers recommend procurement that allows single point responsibility, ensuring walls, stairs and roof are delivered as a single package, reducing the risk of coordination problems.

2.8.5 Rewards

While Crest Nicholson considered that a premium was paid for this system, they also point out that savings were made elsewhere as a result.

Internal space benefits

Using precast concrete party walls between apartments generated greater net internal areas. Party walls could be thinner than conventional double block party walls saving around 50 mm between apartments: a small but significant gain on a large development.

Logistical benefits

Avoiding blockwork in external walls proved to be logistically easier than conventional cavity wall construction and offered savings in terms of much reduced scaffolding. Crest Nicholson's experience was that handling the system was good from a health and safety point of view.

Reduced site storage

Precast units were craned in directly from delivery vehicles as they arrived. This meant reduced site storage requirements without the need for lay-down space for steel – an advantage on a tight inner city site with restricted access where space was at a premium.

Overlapping trades

The speed of construction meant that a reasonable level of weather tightness could be achieved rapidly. This in turn meant trades could be overlapped: following the erection of the first three floors of superstructure, trades could move in below, starting with the screeding. Early installation of precast stair flights facilitated rapid access to upper floors.

Fire resistance

The system offers excellent fire resistance and the risk of fire spread during construction is minimal.

Acoustic performance and associated cost savings

With the Park Central development, the mass of the concrete means that acoustic transmission could largely be addressed without relying on applied finishes, so party wall acoustics were not an issue and material savings were made.

Registered provider feedback

Feedback from the RP, Optima Community Association, on the five blocks constructed appears to be positive, specifically highlighting that unlike other buildings, these did not suffer from shrinkage or cracking.

3 Risks

Table 1 is not exhaustive, but summarises some of the key risks encountered when considering how to build sustainable and innovative homes quickly.

In this context, risks are defined as 'circumstances that threaten the success of a project'. These circumstances could include failing to deliver against a construction programme, compromised durability, health and safety problems, increased cost or many other reasons.

Risks were prioritised and mitigation measures were debated at a stakeholder workshop on 3 June 2011 at BRE, Garston, Watford.

Two factors were taken into account to evaluate the overall risk:

- How frequently is this risk likely to be encountered by clients, designers and contractors when choosing innovative, rapidly built housing projects?
- How severe are the consequences if this risk is not managed?

	Risks	Severity	Frequency	Overall
1	Integrating complex building services (eg MVHR systems) can cause delays and problems onsite if not properly planned	3	4	12
2	The proposed development may not be large enough to allow the manufacturer to produce a sufficient volume of units to deliver the project cost-effectively	3	4	12
3	The changeable requirements of the insurance and mortgage industry	4	3	12
4	The new home may be at risk of high maintenance; the volume of MMC homes delivered is currently quite low and production of systems may be short lived, which may lead to problems with maintenance and sourcing replacement products and materials post-occupation	3	4	12
5	Internal environments resulting from new construction techniques may be unhealthy with potentially huge implications for building occupants if the design does not allow for the implications of issues such as low air permeability	4	3	12
6	Not achieving early design freeze can delay construction; the developer's sales and marketing teams may want to adjust layouts right up to site start. Long manufacturer lead-ins can push back the construction programme, or a factory production slot may be lost	3	4	12
7	Problems securing mortgages and insurance for homes constructed using innovative techniques and technologies	3	3	9
8	Problems experienced onsite because the main contractor for a project does not have a good level of familiarity with a building system	2.5	3.5	8.8
9	The design prepared for planning is not suited to the proposed innovative construction method	2.5	3.4	8.5
10	Failure to achieve satisfactory levels of quality control in the factory and onsite	4	2	8
11	Building inspection is not organised to keep up with the programme causing delays	4	2	8
12	Building inspectors are not familiar with construction type causing delays	4	2	8
13	Non-critical quality control causes delays	2	4	8
14	Components are damaged during delivery/on site	2.2	3.2	7
15	MMC homes may be harder to sell because it is more difficult to offer extras such as the option of moving or removing internal walls	2	3	6
16	Standard details/components that suit every junction are not available meaning these have to be developed with the supplier during the detail design process – this introduces uncertainty and risk	3	2	6
17	Systems that are new to the market may not be supported by technical information required by regulation, eg Psi (Ψ) values (W/mK) for junctions involving the use of SIPs panels in combination with a beam and block floor	3	2	6
18	Design changes are required during construction resulting in reworking/delays	2.2	2.6	5.7
19	Late selection of a system manufacturer resulting in reworking of design/construction information	2.2	2.5	5.5
20	A lack of key trade skills to install components and/or finish construction. The performance of a system depends not only on how it is designed but how it is installed	2.2	2.5	5.5
21	Components are not properly checked at factory or on site	2.2	2.5	5.5
22	Unsuitable/inaccurate foundations; MMC tolerance requirements may be more challenging than respective British Standards for works that support the MMC, such as concrete foundations or blockwork	2.5	2.2	5.5
23	Impact of external factors which extend the programme, such as poor ground conditions	1.5	3.5	5.3
24	An unexpected amount of additional design time is required – particularly in relation to specialist building services	1.5	3.5	5.3
25	Bespoke detailing is not allowed for by the manufacturer and leads to conflict/delays	1.8	2.8	5
26	Picking a system or manufacturer with a very limited track record	1.8	2.8	5
27	Changes in key design team/project team personnel results in loss of critical expertise	2.2	2.2	4.8
28	Using a large palette of materials complicates detailing, slows down design and causes problems on site	2.2	2.2	4.8

	Risks	Severity	Frequency	Overall
29	The design is too dependent on one manufacturer, who may not see the project through	1.8	2.5	4.5
30	Lack of coordination between innovative and conventional construction methods causes problems with junction detailing and programming	2.5	1.8	4.5
31	The build programme is not quick enough to deliver cost savings on contractor preliminaries associated with MMC	1.5	2.8	4.2
32	Lack of standardisation in building planning and layout means the design does not lend itself to the system	1.5	2.8	4.2
33	Confusion about the manufacturer's responsibilities, eg the supplier provides the walls and roof but then agreement must be reached about soffit systems, gable ladders, bolt-on chimneys, roof lights, internal partitions, protection, scaffolding, etc. Resolution may need the involvement of all parties	1.5	2.8	4.2
34	Impact of weather on construction speed	1.8	2.3	4
35	False comparisons with traditional approaches are drawn which suggest a given system will be much quicker than it is	4	1	4
36	Magnification of cashflow and delivery risks using MMC	2	2	4
37	The system supplier's initial appraisal of cost is inaccurate; MMC suppliers may quote conservatively to be competitive but costs can escalate during design	2	2	4
38	The system cannot be adapted to suit necessary unforeseen design changes	1.8	2.2	4
39	A lack of cost certainty because design is not finalised at the time of order	2.2	1.8	4
40	Problems achieving Building Regulations compliance and obtaining other technical approvals	1.5	2.5	3.8
41	Unachievable tolerances are required onsite	1.5	2.3	3.5
42	Precise sequencing of construction is not followed	2.8	1.2	3.4
43	The combination of several innovative techniques on the same project delays the programme	1.5	2.2	3.3
44	Time pressure makes it easier to make mistakes	1.8	1.8	3.2
45	Components are ready for installation, but the site is unprepared for delivery	1.2	2.5	3
46	There is insufficient storage space onsite	1.2	2.2	2.6
47	Traditional frameworks do not allow cooperation between designer, contractor and installer, leading to conflict	1.2	2.2	2.6
48	The construction method is fundamentally unpopular with potential owners	1.5	1.5	2.3
49	Cost inflation of the system or system components during the construction phase	1.2	1.5	1.8
50	A different building inspector is used in the factory/onsite leading to confusion	1.5	0.8	1.2
51	Problems getting planning permission	0.5	2.2	1.1

Key

Each column of the table above is graded independently according to this scale.

4 Recommendations

The following recommendations are aimed at mitigating some of the key risks at typical project stages.

Design

Risk	Control measures
Not achieving an early design freeze can delay construction; the developer's sales and marketing teams may want to adjust layouts right up to the start of work on site. Long manufacturer lead-ins can push back the construction programme, or a factory production slot may be lost.	All relevant teams within a developer organisation including sales and marketing teams should be encouraged to engage with a project prior to detail design commencing, signing off site layouts and floor plans of dwellings where possible. Good communication between the client, design team and supplier should ensure that the importance of timely decision making is highlighted. It may be feasible to agree a design programme that includes multiple-staged client sign-offs. These could be, for example, linked to RIBA Work Stages. Good communication ensures that the design team's work is coordinated and that the design progresses through consensus resulting in fewer surprises which cause delays. Any other measures that improve teamwork and design coordination over the long term should be considered, including supply chain partnering. Looking forward, building information modelling (BIM) is likely to become more commonplace[20]. The opportunity will be available to use BIM to rapidly investigate and coordinate changes prior to design freeze.

Risk	Control measures
Using a large palette of materials can complicate detailing, slow down design and cause problems onsite. Systems that are new to the market may not be supported by technical information required by regulation, eg Psi (Ψ) values for junctions involving the use of SIPs in combination with a beam and block floor.	System manufacturers could help designers by developing and publishing details for a variety of cladding types. Manufacturers should develop a better understanding of other products that developers regularly use to ensure their systems can be sold with typical junction details resolved and with technical information, such as Psi values, provided. Multiple finishes are sometimes specified by designers to counter the perception that system-based forms of construction are bland and monotonous. Manufacturers and designers could do more to demonstrate that this is not necessarily the case. Prior to construction commencing, all complex junctions should be properly catalogued to ensure the appropriate parties are given the responsibility for producing the detail and implementing it on site. Accredited construction details developed to satisfy Building Regulations will have an impact on complexity of detailing and may, initially at least, discourage extensive use of mixed materials.
Risk	**Control measures**
Integrating complex building services (eg mechanical ventilation heat recovery systems) can cause delays and problems on site if they are not properly planned.	Services design and distribution must be integrated at the earliest opportunity and it is wise to allow more time for design-development coordination to avoid wasting time solving problems onsite. Keep it simple. Design changes may be inevitable, but designers should restrict themselves and impress on clients the need to keep these to a minimum. The arrival of BIM will make it easier to understand the impact of design changes. MMC suppliers must also help take a lead here and help ventilation designers understand what is possible with their system. Often the two suppliers sit back and wait for each other.
Risk	**Control measures**
Problems achieving compliance with Building Regulations and obtaining other technical approvals.	Use only one innovative system to simplify the process. Use systems which already have approvals, eg BBA certification. If technical approval looks complex, ask NHBC to get involved at an early stage. If several systems have to be used together, use combinations of systems that have been used previously and, preferably, combinations that have been reviewed by NHBC. Currently certificates may not cover every detailing eventuality so developers and designers are left to manage the risk of designing one-off solutions. Finalise construction details before building work begins to avoid surprises on site. Developers and contractors should manage their supply chains so that integrated solutions are generated with fully compatible components where possible.
Risk	**Control measures**
An unexpected amount of additional design time may be required.	Fix the design as early as possible and do not change it. Early involvement of the manufacturer as part of the design team can reduce the likelihood of additional design work.

Procurement

Risk	Control measures
Picking a system or manufacturer with a very limited track record.	Picking a manufacturer or a team without relevant experience should be avoided Procurers should look for: ■ membership of a trade association ■ performance bonds (parent guarantees) ■ NHBC approval, or make their own investigations. Developers should involve their whole design and construction team to talk through every part of the system so that all parties know what is required of them. Seek assurance of the supplier's ability to ensure longevity of supply of components that may need maintenance or replacement post-occupation.

Construction

Risk	Control measures
Problems experienced on site because the main contractor does not have a good level of familiarity with a building system.	Early involvement of the supply chain and the main contractor can help ensure that the system supplier and contractor understand roles and responsibilities. Contractors could improve their understanding of alternative forms of construction through training and better communication with their supply chains. Similarly, more introductory and explanatory information from the supply chain about their products could be provided, which would help contractors to prepare before construction. Continuous involvement of a novated design team can ensure that there is continuity between design and delivery. The risks involved in handing over the detailing of a design to a new team are greater with non-traditional construction types. Build full-size sample panels to identify potential problems.
Risk	**Control measures**
A lack of key trade skills to install components and/or finish construction. The performance of a system depends not only on how it is designed but how it is installed.	Risk can be reduced by requiring that product manufacturers are involved with installation rather than assuming that general construction skills are sufficient. Greater encouragement could be given to manufacturers to install their own systems – while it is convenient for contractual reasons for a client to have a single point of responsibility to deal with, there is usually less risk involved when responsibility for assembly is handed to manufacturers. Trade bodies have a role in supporting installers; clients would have greater confidence if it were possible to require installers to hold a certificate of competence under an accredited scheme, thereby demonstrating an appropriate level of skill and experience in particular types of construction work. An industry-led and funded scheme exists for installers of renewable energy technologies (the Microgeneration Certification Scheme) where the link between correct installation and performance has been recognised. Installers can improve by training individuals to understand how their product interfaces with other types of construction. While installers may not be responsible for these elements, it is often at these junctions where things go wrong. Value engineering processes should be managed with care: avoid substituting products that form part of a system – risk is likely to be reduced by employing a specialist to install the entire system. The same principle applies to the appointment of consultants: using inexperienced engineers without the specific skills to design using a system, can ultimately result in a more expensive structure and greater overall cost.
Risk	**Control measures**
Failure to achieve satisfactory levels of quality control in the factory and on site.	Clients should only appoint contractors that can demonstrate that they operate effective quality assurance systems. If circumstances permit, risk can be reduced and clients, contractors and manufacturers can benefit from building trusted long-term relationships (partnering). Contractors required to work with unfamiliar subcontractors/suppliers should be prepared to check everything. Contractors and clients should also clarify handover responsibilities at the outset. At a national level, additional Building Control inspection training may help inspectors to address the technical challenges posed by the proliferation of non-traditional construction types.

Post-construction

Risk	Control measures
Problems securing mortgages and insurance for homes constructed using innovative techniques and technologies.	Manufacturers can seek third party certification of products (eg CE mark, ETAG, BRE, BBA) to demonstrate reliability. Ensuring that product certification makes sense. NHBC approval can be delayed by inconsistent use of product certification schemes, eg products can have third party certification from two different sources covering different aspects of performance. Products should be used as they are intended to be used. Certification may cover products for use in a particular way, but not as intended for a given project. Single point responsibility assumed by the supplier for design, manufacture and installation simplifies matters.
Risk	**Control measures**
Changeable requirements of the insurance and mortgage industry.	Construction industry trade associations have a role in communicating requirements to members. Additional training may be beneficial. Manufacturers should seek BRE and NHBC approval as a robust indicator of reliability to mortgage lenders. A central body capable of representing the interests of both Council of Mortgage Lenders and the Association of British Insurers would help clarify requirements for manufacturers.
Risk	**Control measures**
Internal environments resulting from new construction techniques may be unhealthy with potentially huge implications for building occupants.	This is an area of considerable importance and much debate; many of the issues are equally applicable to conventionally constructed homes. Further evidence from post-occupancy evaluation is required to demonstrate that: ▪ internal air quality is not adversely affected by the use of some new construction techniques and materials. Concerns about off-gassing of vapours from some wood and insulation products need to be addressed ▪ overheating risk, particularly with lightweight systems, can be managed ▪ limited maintenance is required over the lifetime of dwellings to sustain a comfortable and healthy internal environment. Low air permeability targets required by Building Regulations mean that design features to reduce moisture levels may be required, eg keeping drying spaces away from living accommodation, or providing drying cupboards. System manufacturers need to anticipate occupant behaviour – will mould growth be encouraged by an occupier turning off a mechanical ventilation system?
Risk	**Control measures**
The new home may be at risk of high maintenance and future adaptability may be limited.	Designers should consider how future uses of the building can be accommodated at the outset. Clients should check for information about the durability and reliability of the system (eg NHBC approval). Designers and contractors should consider how interfaces between materials will be handled, especially cladding, and particularly if more than one subcontractor is involved. Materials and products should be chosen that are easy to adapt and replace where possible (eg bolted rather than glued). Designers should consider how detailing will allow the building to be extended over its lifetime. MMC suppliers may be outlasted by their buildings so designers should consider how buildings can be maintained if the supplier is no longer able to provide replacement components.

4.8.1 Risk management checklist

A risk management checklist is included in the Appendix to assist clients, manufacturers, design teams and contractors considering using innovative techniques on a new project.

5 Conclusion

Risks to the success of a new development span all stages of a project; clients, designers, manufacturers and contractors all share responsibility for ensuring that a well-designed project is safely delivered on time and within budget expectations.

5.8.1 Social housing providers

Social housing has seen the greatest experimentation with rapid construction methods and it is RPs who have developed some of the most successful techniques for dealing with risk. A vested interest in reducing long-term maintenance has driven a focus on reducing defects.

Successful, long-term relationships exist between clients, contractors, manufacturers and their supply chains, as demonstrated by the Castlefields Estate Regeneration development. Investment in these relationships has allowed trust between participants to grow, while generating sufficient volumes of homes through manufacturers' factories to realise cost benefits for the client. The persistence of social housing providers, encouraged by incentives from Government, has enabled these teams to evolve methods of working based on the experience of several phases of construction. This has let them judge which systems work best and minimise defects.

The advantages of building quickly are obvious for RPs: short construction programmes mean existing residents are not displaced for long and accommodation is available for rent sooner. New occupants are usually available to move in straight away. Nevertheless, in the current downturn, RPs are increasingly risk averse, aware of their potential liabilities including the need to preserve funds for the maintenance and refurbishment of their existing stock.

5.8.2 Private house builders

Private developers offering new housing to home-owning customers in the UK have, in general, had a more difficult time justifying some of the risks necessary to build quickly. The benefits of building fast are less clear, particularly in a downturn where sales are slow and building out a development gradually may be more cost effective.

Some developers have taken a view that being at the forefront of innovative, sustainable construction is key to long-term profitability, and is a way of maintaining reputation and securing more land – but innovative construction does not necessarily mean rapid construction. The Lime Tree Square project is an award-winning piece of urban design built using a system that might have led to programme savings, but which, in the event, was built at a speed comparable with conventional techniques.

The Adelaide Wharf development demonstrates that private sector developers are able to transfer skills from commercial projects in a way that contractors working exclusively for providers of affordable housing cannot. The resulting hybrid of modular construction and optimised use of conventional techniques has been a success and is in many ways a model for similar developments.

There will always be examples where the need to build quickly may be driven by specific factors, such as a need to minimise disruption to a neighbourhood or other unusual programme constraints. Developers looking to maximise the speed and cost benefits of MMC systems should recognise above all that conventional approaches to project management will not work for the reasons given below.

- Areas of decision making left pending in conventional construction often cannot be put on hold.
- Early commitment to a design may be essential, with the disadvantage that the developer's flexibility to adjust the mix of dwelling types at a late stage to respond to market activity may be lost.
- Responsibilities and roles onsite may need to be agreed when selecting a supplier, which may seem very premature.
- Stages of a traditional project may need to be reversed, with tendering required at an early stage in order to involve a supplier in the design stages.
- 'Interference' of the manufacturer in the design process should be encouraged rather than prevented to help deliver a more buildable, commercial design.
- Securing planning consent using the design flair and MMC system expertise of designers, then swapping to lower cost consultants for delivery of detailing and control on site may be a false economy.

Clients should take some comfort from the assertion that few mistakes on their own lead to catastrophic failure; the rare examples that exist illustrate that a combination of factors must be involved. Ultimately, for some clients, judgements about whether breaking with conventional methods was a risk worth taking will have to wait some years. Then we can judge whether a focus on innovation and speed has produced durable and healthy homes that can stand the test of time.

Appendix
Risk management checklist

Client

- Is the proposed development large enough to allow the manufacturer to produce a sufficient volume of units to deliver the project cost-effectively?
- Is the local planning authority likely to have a significant objection to the proposed form of construction and if so, is a planning application unlikely to be successful?
- Is it unavoidable that changes will be made to the design during the construction phase and if so, has the potential impact on the programme been considered?
- Is the client prepared to manage the lack of cost certainty if time pressures dictate that a system is ordered with design and specification work not finalised?
- Are there doubts about whether use of the system will mean that units in the proposed development will be insurable or mortgageable?
- Is there budget contingency to cover the possibility that the supplier's initial appraisal of the construction cost may be inaccurate?
- Can the manufacturer be appointed with sufficient time to contribute to the design of the development?

Supplier/manufacturer

- Can the manufacturer/installer demonstrate a track record with similar projects?
- Does the system manufacturer's lead-in time require a timescale to be set for design freeze and if so, can the design team meet this timescale?
- Is the proposed system suited to the design with applicable construction details already developed, or will a considerable amount of additional design time be required to develop further details?
- Are the proposed building services simple to integrate with the chosen form of construction or will additional design time be required?
- Can the manufacturer demonstrate that the proposed form of construction will deliver a healthy internal environment for occupiers in the short and long term?
- Are suppliers' claims about construction speed realistic, or are false comparisons being drawn with conventional techniques in order to make a point?
- Can the proposed system accommodate bespoke detailing required by the design team?
- Are components likely to be subject to significant cost inflation as a development is built out and if so, has this been taken into account?
- Does the manufacturer have a robust quality assurance system? Do they need to check components as they leave the factory or when they arrive onsite?

Design team

- Does the design lend itself to a repetitive form of construction, or to variations from standard house types mean that additional design time will be required?
- If proposals have already achieved planning consent, is it possible to build the scheme using the proposed system without fundamentally changing the design, especially storey heights?
- Does the design take into account the potential need to adapt the dwelling in future to suit different floor plan configurations?
- Is the design team intending to use a large palette of materials and if so, has sufficient time been allowed to detail all of the junctions robustly?
- Does detailed knowledge of the system sit with only a few individuals and if so, can the design/delivery team cope with personnel changes?
- If the selected manufacturer withdraws from the project (eg following financial difficulties) can the design readily be adopted by another manufacturer?
- If a combination of construction techniques is to be used, will this compromise the overall speed of construction?
- Have steps been taken to ensure that, as far as possible, the building will have a low maintenance requirement?

Main contractor

- Does the contractor have a track record with the proposed form of construction?
- Is the contractor confident that the key trade skills necessary to complete construction will be available?
- Is the contractor committed to using competent installers and if so, how will this be monitored?
- Have clear lines of responsibility been set defining the limit of the manufacturer's design responsibility and role on site?
- Can the required construction tolerances for foundations be achieved?
- Has sufficient priority been given to enabling works and site preparation requirements of the system to allow construction work to begin promptly?
- Are the timescales allowed in the programme realistic or will unreasonable time pressures result in mistakes and shortcuts on site?
- Are aspects of the build delivered by other subcontractors (eg foundations, external works) fully coordinated with the proposed system?
- Is installation of the proposed system affected more significantly by adverse weather conditions and if so, has this been factored into the construction programme?
- Have suitable steps been taken to ensure that system components are properly protected during delivery and when stored on site?
- If the integrity of a system depends on a precise sequencing of construction being followed, how will this be controlled?

Technical approvals

- Are the proposed building inspectors familiar with the intended form of construction?
- Can a programme for building inspection be agreed that will keep pace with the proposed speed of construction?

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Further reading/web sites

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Lime Tree Square
Kingspan TEK BBA Certification: www.tek.kingspan.com/uk/pdf/tek_bba_certificate.pdf

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CABE case study: www.cabe.org.uk/case-studies/lime-tree-square

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NHBC Foundation recent publications

Lessons from Germany's Passivhaus experience

The Passivhaus movement in the UK is in its infancy, and while it has many enthusiastic advocates, others question its viability as a standard for volume house building. Worldwide, since the standard emerged from Germany in the late 1980s, some 37,000 Passivhaus buildings have been constructed.

This report examines the political, economic and social drivers, as well as the general attitudes, that have helped or hindered the uptake of Passivhaus in its birthplace. The German context is compared with that of the UK, and the relevance of Germany's experience to the UK is discussed. ***NF 47*** December 2012

Overheating in new homes: A review of the evidence

There is increasing evidence that new and refurbished properties are at risk of overheating, especially small dwellings and predominantly single-sided properties where cross ventilation is not possible. Further, there is evidence of overheating in prototype houses built to zero carbon standards, indicating a lack of cross ventilation in lightweight, airtight houses with little or no solar shading.

This report reviews this evidence, the causes of overheating and the consequences for health. It gives guidance on reducing overheating and calls for a universally accepted definition of overheating in dwellings and threshold temperature levels for use by planners, designers, builders and local authorities. ***NF 46*** November 2012

The use of recycled and secondary materials in residential construction

The use of recycled and secondary materials as aggregates in construction for applications such as pipe bedding and concreting aggregate (as well as in the more `traditional' uses as `hardcore', fill and road materials) is increasing.

This clear, detailed and practical guide describes how to source, correctly specify and use secondary and recycled materials in residential construction (illustrated by case studies and examples). It also provides key information on how to avoid incorrect use (and consequent unsatisfactory performance) of recycled and secondary materials. ***NF 45*** August 2012

NHBC Foundation publications can be downloaded from **www.nhbcfoundation.org**

NHBC Foundation publications in preparation

- Building Information Modelling: An introduction for house builders
- Cellulose-based building materials

NHBC Foundation

Housing research in partnership with BRE Trust

www.nhbcfoundation.org

Building sustainable homes at speed – Risks and rewards

New construction techniques have presented the house-building industry with the opportunity to combine the benefits of building quickly and building sustainably to meet the requirements of the higher Levels of the Code for Sustainable Homes. House builders considering using innovative systems are faced with difficult judgements about whether these approaches can fulfil their objectives and produce durable, healthy, low-maintenance housing.

This research review gives a series of case studies of selected sustainable housing developments which had the potential to achieve significant gains in construction speed by using innovative approaches. It summarises the risks that house builders, registered providers, manufacturers and design teams should be aware of when considering how to build sustainable homes quickly, highlights the risks that are of most concern and suggests how the most significant risks can be avoided or mitigated.

The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the UK's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.

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Housing research in partnership with BRE Trust