SCI PUBLICATION 328

Case Studies on Residential Buildings using Steel

The Steel Construction institute

The Steel Construction Institute

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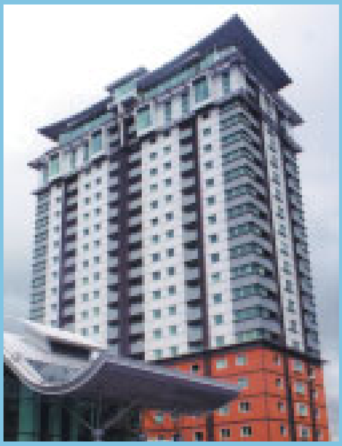
These case studies and further information on light steel framing can also be obtained from: http://www.steel-sci.org/lightsteel



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Developer, Westpoint Homes, chose *Slimdek*® for its prestigious 8-storey residential block in the centre of Glasgow because off-site pre-fabrication and speed of steel construction led to more rapid completion within a tightly controlled cost plan.

Glasgow Miles Better for *Slimdek*®

Slimdek®

Excellent acoustic insulation values were obtained from on-site tests. These meet the stricter requirements of the new Building Regulations Part E.

This major residential block is situated on the busy corner of North Street and Berkeley Street adjacent to the M8 motorway at Charing Cross in Glasgow. The L-shaped building is 8 storeys high, with basement car parking and a penthouse on the 7th floor at the corner of the building. There are 49 flats, 8 of which are duplex (2 storey). All were sold in the early stage of the development. Offices are located at street level.

The architects' original design concept was to use concrete floors supported on load-bearing masonry walls with a steel framed podium over the basement car park. However, the structural engineers considered that a completely steel framed building would provide a more effective solution.

The constraints of the site meant there was limited space for storage of materials. There was considerable potential difficulty in the delivery and handling of materials, and the removal of any waste created by traditional methods of construction.

Slimdek® achieves the minimum construction depth without downstand beams. It allowed the client and contractor to benefit from off-site fabrication, accuracy, speed of construction and good in-service performance within the total construction cost limits defined for the project.

The final solution uses 280 Asymmetric *Slimflor* Beam (ASB) sections supported on Square Hollow Section (SHS) columns with Rectangular Hollow Section (RHS) edge beams within a floor depth of only 300 mm.

Steel lift shaft frames were used to provide structural stability to the frame and steel staircases provided internal access to all levels during construction.

Spans of 7 to 9 m were achieved by the ASB beams, giving the architect complete flexibility in the internal planning.

All internal walls used plasterboard and sound check boards on lightweight steel framing to minimise the load on the frame and also to reduce the use of wet trades. All SHS columns were enclosed within the wall construction, reducing the need for further fire protection and increasing speed of construction.

The building is clad with a mixture of brickwork, rendered blockwork and stone, with copper-faced mansard slopes, copper and composite panels on the roof.

Glasgow Miles Better for *Slimdek*®

Technical details

Slimdek®

Application benefits

- Speed of construction
- Minimum storage of materials on site
- Non-combustible construction
- Excellent acoustic insulation
- Good in-service performance
- Shallow construction with facility for service distribution
- Cost effective construction system

Project data

Client
Westpoint Homes Ltd

Architect
Maxwell Design Consultants

Structural Engineer
Walton Garden & Partners

Contractor
Beechwood Developments Ltd

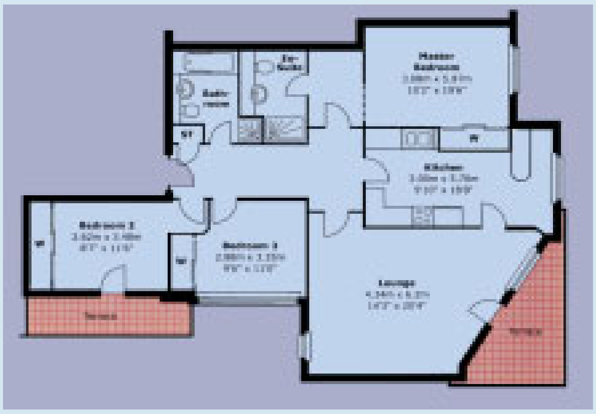
Steel Fabricator
Bone Steel Ltd

Decking
Corus Panels and Profiles

Construction details

The 280 ASB 100 beams support SD225 deep decking and span up to 9 m between SHS columns. The columns are of minimal cross-section (120 mm square) and were designed to fit within the separating walls.

At each floor, the ASBs run over the capping plate of the SHS columns, thus minimising the deflections by developing continuity of the beams, which were delivered to site in lengths of up to 15 m. The baseplates on the SHS columns of the next storey sit on top of the ASBs, which are stocky enough to transfer the compression load through to the column below.



The edge beams are 200 x 100 mm RHS with a 15 mm thick steel plate welded to the bottom which supports the deep decking. It provides a neat edge to the floor. The overall slab depth is 300 mm.

For enhanced resistance to impact sound, a flooring system using timber battens with a resilient layer on a mineral wool quilt, supplied by J Danskin and Co Ltd, is used. The battened floor system readily permits the distribution of services across the floor. The acoustic test results for the as-built project are given below. The results are considerably better than the new Part E of the Building Regulations and also the enhanced *Quiet Homes* standards.

Acoustic test results for the *Slimdek*® separating floor

	Airborne sound reduction		Impact sound transmission	
	$D_{nT,w}$	$D_{nT,w}+C_{tr}$	$L'_{nT,w}$	$L'_{nT,w}+C_i$
Current Building Regulations (mean)	≥52 dB		≤61 dB	
Proposed Building Regulations*		≥45 dB		≤62 dB
Enhanced (*Quiet Homes*) Standard*		≥50 dB		≤57 dB
Average sound reduction	**62 dB**	**54 dB**	**48 dB**	**49 dB**
Diagonal sound reduction	**65 dB**	**58 dB**		

** Including spectrum adaptation terms.*

Road-side view of building

Decking supported by ASB beams

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***Slimdek®* was chosen for this prestige harbour-front project after a value engineering study had demonstrated its benefits. Significant savings were achieved over the original reinforced concrete design.**

High Quality Apartments using *Slimdek®* at Portishead Marina

Slimdek®

By a slight adjustment of column positions, the *Slimdek®* design was able to eliminate the expensive transfer structure at ground floor level, as well as reducing foundation loads by 30%.

Portishead Marina is a major redevelopment of the former docks area, which involves a variety of 2 and 3-storey houses and a 6-storey apartment block on the harbour front. The town houses in some of the phases were constructed using Corus' *Surebuild* system. The 6-storey block was originally designed in reinforced concrete but the developer, Crest Nicholson, wished to reduce the piled foundation costs.

A value engineering exercise was used to evaluate various alternative schemes, one of which included *Slimdek®*. The design also included a below ground car park and, by a slight adjustment of column positions, the *Slimdek®* design was able to eliminate the expensive transfer structure at ground floor, as well as reducing foundation loads by 30%. The overall savings were significant and led to the final choice of *Slimdek®*.

A range of apartments of 46 to 62 m^2 floor area each have large panoramic windows and some have prefabricated balconies. Columns were designed to fit in the separating walls and façade walls. The chosen cladding was brickwork to create a more traditional 'feel' for this riverside perspective. Other buildings used an insulated render system above first floor and brickwork at ground floor.

Floor spans of *Slimdek®* ranged up to 5.5 m, which allowed the use of 2-bay car parking below ground. The 1 hour fire resistance was achieved by the partially encased ASB beams and bar reinforcement placed in the ribs of the deep decking.

A further 6-storey building in this project is under way using *Slimdek®*, building on the success of this phase.

Surebuild used in the 3 to 4-storey buildings

High Quality Apartments using *Slimdek*® at Portishead Marina

Technical details

Slimdek®

Application benefits

- Light weight, which leads to reduced foundation loads
- Column grid compatible with below ground car park
- Elimination of concrete transfer structure
- Good fire resistance
- Bay windows achieved by the framed structure
- No temporary propping

Project data

Client
Crest Nicholson Homes

Architect
Austin Smith Lord

Structural Engineer
Nicholson Jones

Steel Fabricator
Bison Structures

Decking
Corus Panels and Profiles

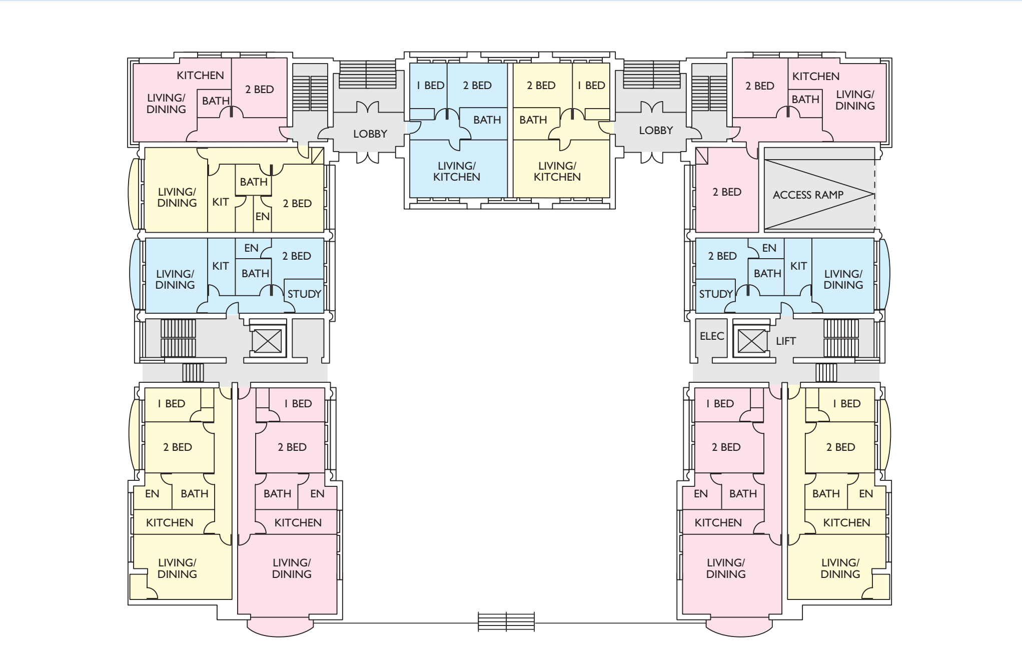
River view of apartments

Construction details

The steel structure consists of 280 ASB 100 sections spanning up to 5.5 m between steel columns, which are located in the separating walls. The 300 mm deep composite slab spans between cross-walls and did not require temporary propping. Plasterboard was fixed on resilient bars directly attached to the decking. A heavy duty mineral wool layer and floor boarding provided the impact sound insulation (the slab and ceiling on its own was sufficient for airborne sound insulation). The completed floor depth is only 400 mm.

The discrete columns and flat soffit meant that the non load-bearing walls could be placed to suit the required floor plan of the apartments. Large bay windows were located between the columns. The column spacing was carefully selected in order to suit an efficient layout for car parking which eliminated the need for a transfer structure of ground floors. The car park area was sufficiently well ventilated in order that it could be designed for 1 hour fire resistance without additional protection. Stability was provided by braced stairwells and lifts.

The self weight of the structure and imposed loading was only 70% of that of the original 250 mm reinforced concrete flat slab which, with the loss of the transfer structure, meant that foundation loads and piling costs were reduced by 30%. Speed of construction was also improved by some 30%, which lead to associated savings in cranage costs and site preliminaries. Pre-fabricated balconies were directly attached to the perimeter of the slab to improve the speed of installation further.



Plan view of typical floor

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Slimdek® was chosen for this tight infill residential development of 42 luxury flats in central London, partly re-using the listed external walls of the existing building on the corner site. Excellent acoustic insulation of the _Slimdek_® floor was demonstrated by on-site tests.

Slimdek® Proves its Colours at Harlequin Court, Covent Garden

Slimdek®

The *Slimdek*® system was chosen for its speed, reduced space requirements on site, reduced floor to floor heights, and reduced floor loading.

Steel framing is increasingly being used in city centre residential buildings, particularly on tight sites where access and space for storage and handling of materials are at a premium. In these residential projects, speed and quality of construction are important. In addition, such sites often have restrictions on use of existing foundations or the size of new foundations, which favours the reduced self weight of steel solutions when compared to reinforced concrete.

Harlequin Court, located at Covent Garden in Central London, is a new-build and refurbishment project by developer Artesian, providing 42 new high quality apartments for sale. The 4 to 8-storey building consists of about 4,000 m^2 of refurbished structure and 2,000 m^2 of new-build, which partly retains the existing masonry façade. It creates a new residential building with additional retail and commercial space on the ground floor.

Block C is the new-build part of the project and consists of 20 apartments built using the *Slimdek*® floor system. The *Slimdek*® system was chosen for its speed of construction, reduced floor-to-floor heights, and reduced loading. The *Slimdek*® design consists of spans of generally about 5 m to 7 m for the beams and about 5 m for the deep composite decking.

The design features a round central court which has a highly glazed façade and includes balconies from some apartments. The façade onto Tavistock Street is listed and had to be retained, so the *Slimdek*® floors were constructed to abut the inside face of the masonry and the steel columns were set slightly back from the wall.

Slimdek® Proves its Colours at Covent Garden

Technical details

Slimdek®

Application benefits

- Rapid construction system
- Excellent acoustic performance
- Lightweight construction reduced foundation loads
- No temporary propping during construction
- Shallow floor depth (for façade retention)
- Suitable for cramped city centre site

Project data

Developer
Artesian

Contractor
Miletrian plc

Architect
Goddard Manton Partnership

Structural Engineer
Cameron Taylor Bedford

Steel Fabricator
SCWS

Decking Supplier
Corus Panels and Profiles

Construction details

The 8 storey steel frame consists typically of 203 mm by 203 mm UC columns generally on a 5 m grid with 280 mm Asymmetric *Slimflor* Beams (ASBs) supporting SD 225 decking to create a 300 mm deep composite floor slab. At these spans, the decking does not require propping during construction. Bracing is provided by a concrete lift and stair core, and fire resistance to the columns is provided by 25 mm of mineral wool and 12.5 mm fire-resisting plasterboard.

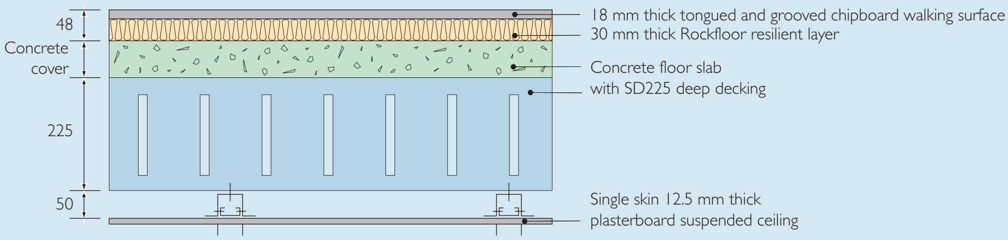
To achieve excellent insulation against impact sound transmission, the floor covering consists of 35 mm of dense mineral wool covered by an 18 mm thick chipboard. Ceilings consist of 12.5 mm thick plasterboard fixed to the underside of the deck using a proprietary fixing system with a small void between the deck and plasterboard for services. This gives a compact overall ceiling to floor zone of about 400 mm, and services can be accommodated between the ribs of the decking. Post-completion acoustic tests showed that the floor achieves very good acoustic insulation, considerably better than both current and proposed future Building Regulations requirements (see Table 1).

Separating walls consist of light steel double stud construction using 2 x 75 mm steel studs with 25 mm of mineral wool within one layer and 19 mm plasterboard and 12 mm sound resistant plasterboard finish on both sides. Where possible, separating walls align with beams but where this is not the case, special details are used to ensure that the space between the ribs of the decking is closed off for acoustics and fire purposes.

Table 1: Acoustic test results on separating floors

	D_{nTw}	$D_{nTw}+C_{tr}$	L'_{nTw}
1992 Building Regulations	Mean > 52 dB Min > 48 dB		Mean < 61 dB Max < 65 dB
2003 Building Regulations		>45 dB	< 62 dB
Mean measured performance	62 dB	55 dB	43 dB

External walls consist mainly of 215 mm blockwork finished externally with 60 mm EPS insulation and a proprietary acrylic render, and internally with dry lining plasterboard. One elevation consists of an existing masonry façade, and the courtyard features a glazed façade.



Detail of acoustic insulation used for the separating floor in *Slimdek*®

Round central courtyard overlooked by new-build apartments

Plan view showing apartments

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Manchester has become an oasis of steel construction by the catalyst of the 2002 Commonwealth Games. Developer Crosby Homes' confidence in the booming market for residential buildings is evidenced by the 19 storey, mixed residential and commercial project.

Britain's Tallest Residential/Commercial Development in Manchester

Composite Construction

The structure has a unique feature of a storey-high steel transfer truss which supports the upper 14 floors in composite construction.

Conceived as a steel-composite structure, No 1 Deansgate is the largest residential building since London's Barbican in the 1970s, and the tallest in steel in the UK. A podium level allows for pedestrian circulation below the residential block. It links with the Shambles area, re-built since the 1996 bomb devastation.

Ian Simpson Architects worked closely with structural engineers, Martin Stockley Associates (MSA), to develop an innovative and exciting design concept within the client's cost schedule. MSA had previously worked with Crosby Homes on another multi-storey steel residential building at the opposite end of Deansgate.

The chosen structure is more readily associated with multi-storey steel framed commercial buildings, but is given a unique feature by a storey-high steel transfer truss which supports the upper 14 floors, and is itself supported by inclined tubular steel columns. Although structurally complex, the building retains an apparent simplicity and lightness.

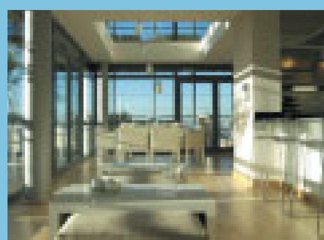
The 84 apartments including eight penthouses were provided with a fully-glazed façade and a 'buffer zone' externally for regulation of internal temperatures. The inner skin is double glazed and the outer skin comprises fully openable single glazed louvres.

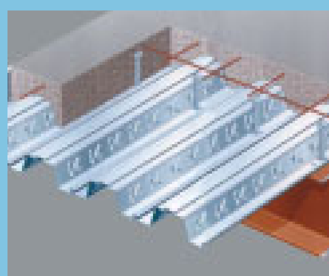
The grid size of the residential block is based on a 4.1 m x 6.8 m column spacing, and secondary beams are eliminated by use of a long spanning composite slab. The shallowest sensible structure was achieved by the use of Universal Column (UC) sections as beams. The steel structure had to be constructed within accurate tolerances to facilitate installation of the glazing.

The building is also innovative in that it has been 'fire engineered' to evaluate the fire risk and structural behaviour in fire, leading to considerable savings in fire protection costs.

Despite its 60 m height, the building is relatively lightweight and uses existing foundations, where possible. Construction of the concrete sub-structure started in mid-2000 and the building was opened in mid-2002. Importantly, 80% of the apartments were pre-sold, a reflection of the perceived value of the property.

This project highlights the design opportunities using steel in the medium and high-rise residential sectors especially in urban locations, where there is a premium for speed of construction, and reduced disruption due to construction process.





Ribdek 80 achieves 4.1 m spans

The Steel Construction Institute

Britain's Tallest Residential/Commercial Development in Manchester

Technical details

Composite Construction

Application benefits

- Multi-storey construction
- Fully glazed façade to tight tolerances
- Speed of construction and early fit out
- Minimises foundation work
- Open podium structure for pedestrian circulation
- Fire engineered to reduce fire protection costs
- Reduced disruption to city centre

Project data

Developer
Crosby Homes

Architect
Ian Simpson Architects

Structural Engineer
Martin Stockley Associates

Construction Manager
MACE

Steel Fabricator
Wescol Glosford

Decking
Richard Lees Steel Decking

Construction details

The upper 14 floors, typically of 60 m x 17 m external plan, comprise a regular steel structure in which a 4.1 m span composite slab is supported by 6.8 m span composite beams using 203 mm UC sections that are perforated for ducts serving the internal kitchens and bathrooms. The 165 mm thick composite slab uses *Ribdek 80* decking and has a 40 mm screed. A suspended ceiling, comprising two layers of 15 mm fire resisting plasterboard, enhances the inherent fire resistance of the UC sections to provide the required fire resistance and to economise on fire protection costs.

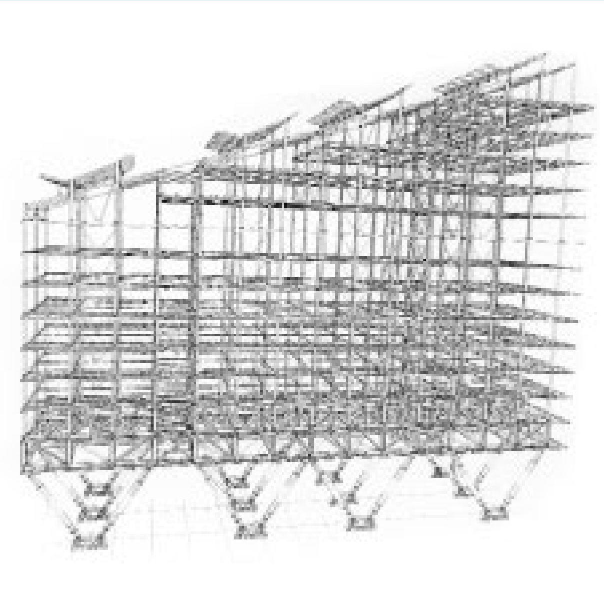
At 16 m above ground level, the upper residential block is supported by a storey-high steel transfer structure to reduce the wider grid of the retail area below to the sensible residential grid. This is achieved by two directional trusses supported by inclined tubular legs, which were designed to be architecturally interesting at the podium level as well as structurally functional. The longitudinal transfer structure was erected as large braced sections fabricated from UC sections and cruciforms from 40 mm steel plate.

Construction Manager, MACE, and the steel fabricator developed an innovative temporary platform from which the floor beams could be erected rapidly, and safely. The platform was raised as the work progressed. Decking followed on the floors beneath and stabilised the structure. The UC sections were propped to reduce deflections.

The erection of the 800 tonne steel structure took only 30 weeks, representing an average of one floor every two weeks, including the complex transfer structure. The columns are UC sections located within the separating walls. The smallest possible circular hollow sections are used where the columns are exposed adjacent to the glazed façade.

The outer skin of glazing is suspended from the floor above and the structure was designed to tight tolerances and minimum movement.

Separating walls used double layer light steel sections with two layers of 15 mm fire resisting boards on each side with insulating quilt between to provide a high level of acoustic insulation. The mass of the floor and its fire protection achieve the required acoustic insulation for this high quality building.



Layout of structure

Building during construction

Detail of underneath of decking

Inclined tubular legs

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Long span composite construction, using cellular beams, meets strict vibration and acoustic standards for this major hospital project, incorporating residential care facilities, and saves 20 weeks in construction programme relative to site-intensive construction.

Leeds Nuffield Hospital uses Steel-intensive Construction

Composite Construction

The steel frame was erected before the concrete cores in order to achieve early installation of servicing plant and fit-out.

Hospitals increasingly use steel-intensive construction for reasons familiar to designers and owners of commercial buildings: speed of construction, and flexibility of internal layout for current and future requirements. Design and Build constructor, Shepherd Construction, chose long span composite construction for the Leeds Nuffield Hospital because it met the tight construction programme, which would not have been possible with reinforced concrete. It is designed to high standards for both operating theatres and residential care.

The 7 to 8- storey 12,000 m^2 hospital in the centre of Leeds has a high ratio of operating theatres to ward space. The design for these highly serviced areas led to the use of long span cellular beams with facility for service integration. The complex servicing strategy required regular circular openings and also individual elongated openings in the beams.

Common to many hospital designs, the client called for a strict control of vibrations, which required the use of a relatively deep composite slab. Measurements were taken of the floor response due to walking at various paces. The natural frequency was much higher than the range of any exciting frequency and the Response Factor (a function of acceleration) was below the absolute limit of perceptibility required by the client for the operating theatres.

Light steel internal and external walls were installed early in the construction programme and facilitated early fit-out of the space. Modular toilet and bathroom pods were slid into place on the floors. The servicing plant could be installed rapidly on the upper floors (this was on the critical path). Interestingly, the steel frame was erected before the concrete cores in order to achieve the requirement for early installation of plant. It was estimated that 20 weeks were saved relative to site-intensive construction for this 18 month construction programme.

The same technology has been used in other major hospital projects such as at Carlisle, Edinburgh and Gravesend.

The Steel Construction Institute

Leeds Nuffield Hospital uses Steel-intensive Construction

Technical details

Composite Construction

Application benefits

- Speed of construction – not possible with concrete construction
- Early fit-out due to Rapid Dry Envelope
- Low sensitivity to vibrations
- Long span cellular beams permit service integration
- Flexibility in fit-out due to long spans
- Good acoustic insulation of composite floors and infill walls
- Minimum delivery of materials to this inner city site

Project data

Client
Nuffield Hospital

Architect
Carey Jones Partnership

Consultants
Shepherd Design
Waterman Partnership (for client)

Constructor (D&B)
Shepherd Construction

Steelwork
Wescol Glosford and Westok Ltd

Decking
Ward Building Components

Infill Walls
Metsec Steel Framing

Construction details

The steel framework consists of a 18 m x 6 m grid comprising cellular beams of 11 and 7 m span. Two beam sections were used: 863 mm deep cellular beams with 625 mm diameter cells for the wards and 625 mm deep beams with 400 mm diameter cells for the operating theatres. At certain locations in the span, elongated openings were introduced to provide for larger service ducting. Design was carried out using the computer program *Cellbeam*, developed by SCI for Westok.

The composite slab use *Multideck 60*, which supports a 150 mm deep composite slab in general areas, and a 250 mm deep slab in the operating theatre area. This increased mass reduced the sensitivity to vibrations below the required perceptibility level (corresponding to a Response Factor of 1 in the operating theatre areas). In the ward areas, a Response Factor of 2 was achieved by taking account of the large participating mass of the floor area. Measurements of accelerations taken on site before and after installation of partitions confirmed the designer's assumption of the extremely low level of vibration. The measured natural frequency of 8 Hz was over three times higher than the maximum exciting frequency.

The lightweight infill walls and façade (by Metsec) consisted of 150 mm deep C sections which were installed on-site to create a Rapid Dry Envelope as soon as the floors had been concreted. These lightweight walls supported both brickwork and curtain walling. Most internal walls were in lightweight steel, which could be located and moved to suit the hospital's current and future requirements. Materials use, storage and waste were minimised, which was important for this inner city site.

Pre-fabricated toilet and bathroom pods also speeded up the construction operation as they as they were manufactured 'off the critical path'. These pods were made by Portakabin, part of the Shepherd Group, and were installed on the composite floor.

Cellular beams and brickwork support

Light steel infill walls

Entrance foyer

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Modular supplier, Rollalong, team up with architects, The Design Büro and Ayrshire Framing to construct a 7-storey modular building on a steel framed podium for use as a 'mixed' student residence, key worker accommodation and retail premises.

World's Largest Modular/Steel Framed Building in Manchester

Modular and Composite Construction

The modular suppliers worked closely with their architects to offer a 'mixed' steel solution which was completed in a narrow 'window' from February to September 2002.

A total of 1,425 modules in light steel framing were installed over a four month period on the Wilmslow Park site of Manchester University to create the largest modular building in the UK and probably in the world. The 7-storey modular building was constructed on a steel-composite 'podium' structure at first floor, which housed retail premises and a car park below ground.

The super-structure above podium level was originally conceived in timber framing, but was later replaced by a modular steel solution.

The modular suppliers, Rollalong, worked closely with their architects, The Design Büro, to offer a design which could be completed in a narrow 'window' from February to September 2002, in time for the new intake of students. This speed of manufacture and installation would not have been possible in any other form of construction.

The Design Büro already had experience of the *Ayrframe* system used for manufacture of the modules on the nearby Royal Northern College of Music, and produced all the working drawings for manufacture and interfacing with other components.

Rollalong commissioned a purpose-made factory in nearby Wythenshawe and in a few months was able to set up a sophisticated ten-line production of modules over an eight-day cycle of boarding, servicing and fit-out before delivery to site.

The modules formed 945 study bedrooms, and communal areas used pairs of open-sided modules to create larger spaces. A strict quality assurance 'passport' and locked door policy ensured that the modules were checked before installation and were immediately fit for use.

The 'mixed' residential-commercial development also incorporates retail outlets, a health club, 130 key worker apartments (for rent) and six rooms for people with disabilities. The retail and car park levels were designed using a primary steel frame to a column grid based on pairs of modules on the upper floors.

The same team is working on other schemes involving a range of steel and modular technologies for the urban residential sector.

Modules in place before installation of façade

The Steel Construction Institute

World's Largest Modular/Steel Framed Building in Manchester

Technical details

Modular and Composite Construction

Application benefits

- Required construction (60% time saving relative to site-intensive construction)
- High quality manufacture (locked modules until handover)
- Podium structure in composite construction
- Dimensional accuracy
- Reduced site infrastructure
- Reduced waste creation
- High level of safety in installation

Project data

Client
OPAL for University of Manchester

Architect (for client)
Ogden Associates

Contractor
Watkins Jones Construction

Consulting Engineer
Veryards Ltd

Modular Supplier
Rollalong using modular units by Ayrshire Steel Framing

Architect for Modular Supplier
The Design Büro

Modular Consulting Engineers
Peter Dann Ltd

Construction details

The modules use the *Ayrframe* system, which comprises a grillage of C and top hat sections to create an extremely stiff structure with narrow walls. The modules were designed as self-supporting over seven storeys. Manufacture permitted variations in the façade arrangement, and corridors were also integrated into the modules. Standard modules of widths from 2.4 m and 3.6 m were arranged in three, four and five bedroom clusters around kitchens and communal areas, which were also manufactured as modules. Corridors in-built within the modules reduced the site work and achieved weather-tightness during construction. An integrated modular stair and lift shaft was also an important innovation for this project.

The podium structure on which the modules were placed consists of long span I beams acting together with a composite slab on steel decking. The light weight of the modules was important in order to economise in the design of the podium structure. The 175 mm deep composite slab supports the loads from the module walls where they do not align directly with the beams below.

The installation procedure for the modules used a 'man basket' system which was approved by HSE as being the safest method for working at height. A peak installation rate of 28 modules a day was achieved by the 9 man team over the 4 months of the production and installation period on site. Manufacture through-put averaged 10 modules per day on an 8-day production cycle in Rollalong's purpose-made factory nearby. This is the first example in the UK of such a facility set up for one project.

The 'rain-screen' cladding system was selected in order to achieve the rapid-build programme. It generally consisted of terracotta tiles on a sub-structure fixed through the cement particle board facia and back to the modules. On the courtyard area, an aluminium rainscreen cladding was used.

Ayrframe modules in Rollalong's factory

Modules being lifted into place (using man-basket)

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The Steel Construction Institute

Following the success of the Murray Grove project, The Peabody Trust commissioned the Raines Court apartments as the largest affordable housing project in the UK to be built using pre-fabricated modular units.

Raines Court Creates Affordable Housing in North London

Modular Construction

The Peabody Trust is keen to harness developments in construction technology, to set new standards in quality, affordable housing, and to address the recommendations for change set out by the Government's Egan agenda.

Commissioned and developed by The Peabody Trust, and designed and built by a partnership between architects Allford Hall Monaghan Morris, Wates Construction and Yorkon, Raines Court is currently the UK's largest affordable housing project to be built using modular construction.

Raines Court is The Peabody Trust's second modular housing project. It aims to take forward the success of the acclaimed Murray Grove housing scheme to improve speed and efficiency further. The apartments also demonstrate the flexibility of modular construction, which can offer architectural variety to relate the building to its context and to maximise the available space on site to the benefit of the tenants and the developer. It provides larger housing units than at Murray Grove, each with integral balconies to the 2-bedroom apartments, and private entrance lobbies.

This project is pushing forward the use of modular technology by increasing the level of off-site construction, enabling The Peabody Trust to build new, affordable homes more rapidly, and cost effectively. The scheme demonstrates how high quality architecture and design can be achieved using modular construction, to the benefit of the developer, the building occupiers and the local community.

The 6-storey apartment block consists of a T-shape on plan in which the modules are configured to create a private landscaped courtyard at the rear.

The 3.8 m wide modules are used to create eight living/working units at ground floor with the workspace acting as a buffer to the road. Above are five stories of 2-bedroom apartments with a wing of 3-bedroom family accommodation to the rear. A typical 2-bedroom apartment comprises two modules, one with living/dining/ kitchen area and the other with bedrooms and generous bathroom, based on a open plan layout to maximise the usable living space.

The contract period was only 50 weeks from start on site, saving 20 weeks relative to traditional building. The innovative PPC 2000 contract agreement was used. It is a Housing Forum demonstration project.

Modular units and integral balconies

Raines Court Creates Affordable Housing in North London

Technical details

Modular Construction

Application benefits

- Rapid construction system
- Larger modules for living space
- Private access to apartments
- Integral balconies within each apartment
- Live/work spaces at ground floor
- Light weight reduces foundation costs
- Light weight façade

Project data

Client
The Peabody Trust

Main Contractor
Wates Construction

Modular Specialist
Yorkon

Architect
Allford Hall Monaghan Morris

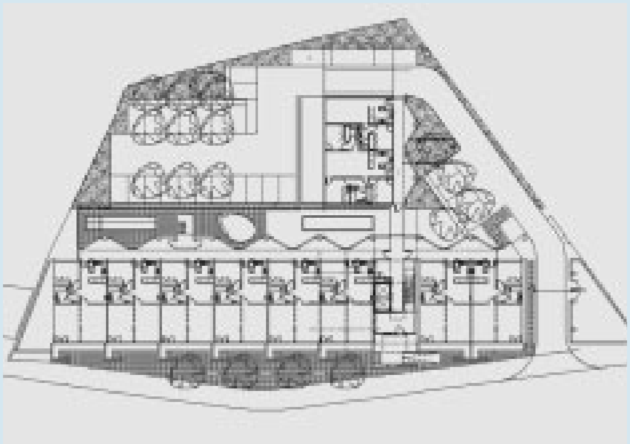
Structural Engineer
Whitby Bird & Partners

M & E Engineer
Engineering Design Partnership

Cost Consultant
Walker Management

Construction details

The 127 room-sized modules are constructed using light steel framing to the Yorkon specification. Generally, the modules are arranged in pairs to create a single apartment. The length of the 3.8 m wide modules varied from 9.6 to 11.6 m, and alternate modules incorporated an integral balcony. The modules are only 3 m high, allowing for a 600 mm floor-to-ceiling space. Structurally, the modules are designed to be self-supported by their corner columns. Stability of the 6-storey building is provided by the group of modules acting together and supplemented by bracing. Erection of the modules took place over a 4 week period.

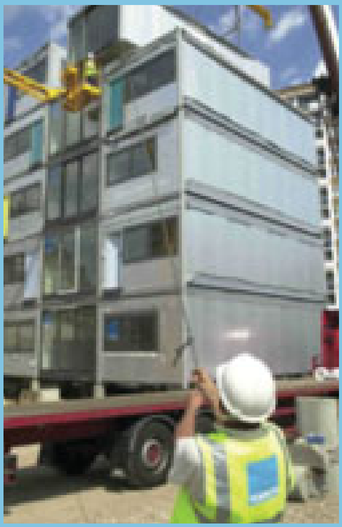


Plan view of site

The façade to the main street is clad with lightweight ship-lap profiled zinc panels, with zinc cover strips to mask jointing. The panels were clipped onto a sub-frame directly attached to the modules in manufacture.

The courtyard elevations were finished with vertical larch timber cladding to add a degree of 'warmth' to the finish of the external envelope. Each apartment has its own unique colour to form a striking composition within the front and rear façades of each block. A patent glazed roof overhang on the sixth floor provides shelter from the weather for the access decks. Square glass screens along the walkway provide further protection outside the entrance to each apartment.

Representation of building showing the set-back and overhangs at second floor level



Installation of modules

Access walkways being installed

Publication P328

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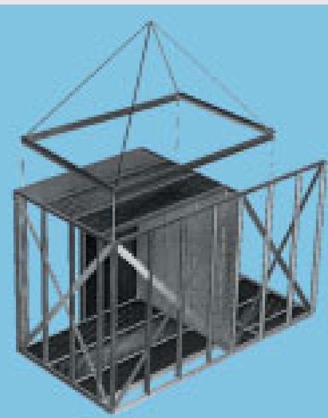
The Peabody Trust chose light steel framing for its social housing development in London, because of experience on other projects, and the requirements for quality and reliability, and speed of construction.

Six-storey Housing using Light Steel Framing and Bathroom Modules

Modular and Light Steel



Pre-fabricated toilet module and its floor cassette

Mixed light steel framing and modular construction was selected for The Peabody Trust's housing project at Lillie Road, Fulham, because it satisfied the client's requirements for speed of construction, improved quality and reliability by off-site manufacture. Specialist constructor, Forge Llewellyn Ltd (now The Forge Company), and consulting engineer, Michael Barclay Partnership, conceived a mixed panel and modular structure, in which all the components were pre-fabricated using light steel C sections.

The project consists of 65 apartments, each of approximately 50 m^2, constructed in three blocks, the largest of which is 6 storeys high. It is on the site of a former school, and for this inner city locality, reduced disruption due to the construction operation was an important client criterion in the choice of methods of construction.

The construction period was reduced to 68 weeks, a saving of 16 weeks on blockwork or concrete construction. Bathrooms were pre-fabricated as modules, which were fully fitted out before delivery to site. The blocks all have a semi-basement car park in *Slimflor* construction. Some exposed or expressed steel elements were used, but the majority of the structure was pre-fabricated using light steel wall and floor panels.

This high level of pre-fabrication allowed the building to be constructed rapidly, and safely, by using the floors as working platforms.

All partners in the project operated under the new PPC 2000 agreement, which encourages 'open book' and non-adversarial relationships. A high level of thermal and acoustic insulation was provided in the building fabric to meet Parts E and L of the revised Building Regulations (2002).

Architects, Feilden Clegg Bradley, also continued the theme of pre-fabrication by choosing a lightweight stack-bonded terracotta tiling system as a 'rain-screen' façade. Aluminium rain-screen cladding was used at higher levels. A sedum roof on the lower blocks reinforces the green landscape.

'Rain-screen' cladding during installation

The construction period was reduced to 68 weeks, a saving of 16 weeks on blockwork or concrete construction.

Front view from Lillie Road

Six-storey Housing using Light Steel Framing and Bathroom Modules

Technical details

Modular and Light Steel

Application benefits

- Modular bathrooms are fully fitted out
- Entirely panel and modular construction speeds up construction
- Robustness for multi-storey application
- High level of thermal and acoustic insulation provided
- Less disruption to the urban locality
- Lightweight cladding

Project data

Client
The Peabody Trust

Architect
Feilden Clegg Bradley

Structural Engineer
Michael Barclay Partnership

Constructor
Walter Llewellyn

Light Steel Framing
Forge Llewellyn Ltd (now The Forge Company)
Ayrshire Steel Framing

Design of bathroom pods
MTech

Construction details

The 6-storey building is made from pre-fabricated light steel panels, floor cassettes, and bathroom modules, all using standard light steel C sections. The wall panels resist vertical and horizontal loads applied to the building, making this building the tallest in the UK using light steel framing as the load-bearing structure. Robustness issues are important for this height of structure, and the structural designer, Michael Barclay Partnership, used SCI's recommendations for tying action to achieve a robust efficient design. Various accidental loading scenarios were also examined, involving removal of whole panels, and the analysis showed that the structure was stable and robust to these extreme events.

Rectangular Hollow Section (RHS) members were introduced as 'expressed' steelwork on the end façades, and also in the balconies. They were installed along with the light steel framing panels.

The bathroom modules were also designed to be structural so that their walls and floors contribute to the resistance to loads. The floor elements used 200 mm deep C sections, and the wall elements used 100 mm deep C sections in 1.2 mm to 2.4 mm thickness, depending on the loads applied. Floors were pre-assembled as cassettes. Cross-walls were braced by cross-flats for stability.

The separating floors and walls achieve an airborne sound reduction of over 63 dB, by use of mineral wool and sound resistant plasterboard by Lafarge. Resilient bars support two layers of plasterboard ceiling. This construction satisfies the new Part E requirements of the Building Regulations.

Various energy efficiency measures were introduced in order to minimise the operation cost of the building, and dwellings will be individually metered. The external walls achieve a U value of 0.2 W/m^2°C for excellent energy efficiency by placing mineral wool between the studs and also external to the wall. This U value is significantly less than in the new Part L requirements of the Building Regulations.

Installation of light steel frames

'Rain-screen' façade using terracotta tiles

Braced wall

Staircase

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The Steel Construction Institute

Century House, a 1960's concrete framed building near Waterloo, has been renovated into 236 high quality apartments using infill walling and a 2-storey roof-top extension in lightweight steel construction without overloading the existing structure.

Twenty-storey Tower Block is Transformed using Light Steel Framing

Light Steel Framing

Century House, near London's Waterloo Station, is famous for being the former home of MI6. Since 1998, the building has not been occupied, but it has now been converted into high quality luxury apartments and housing by developer Crest Nicholson. The existing concrete framed building has been completely stripped out and re-clad to a design by Assael Architecture. New light steel infill walls provide the external envelope and compartment walls between apartments, and a 2-storey roof-top extension provides new luxury penthouses with panoramic views over London.

There were three phases to the project: the first was the renovation of the existing 20-storey building, creating 9 apartments per floor, together with a 2-storey roof-top extension; the second was the renovation of a 5-storey building including 16 apartments; the third (for shared ownership) is a new building acting as a reception and below-ground car parking area. The conversion and new-build created 80 residential apartments for sale and a further 56 apartments for Metropolitan Home Ownership.

The cladding to all buildings is a combination of a metallic cladding panel and a lightweight terracotta tile system which are attached to horizontal rails screwed through the external insulation to the light steel infill walls. The light steel C sections provide the required resistance to wind loads and support the self weight of the cladding. The infill walls are installed on-site in order to accommodate the dimensional inaccuracies of the existing concrete frame. Importantly, the lightweight walls do not overload the existing structure, allowing two additional floors to be built for the same self weight as the former concrete block walls.

The internal compartment and partition walls have been designed to give excellent acoustic insulation and fire resistance properties when finished with two layers of fire resisting plasterboard per side. The same insulation also reduces external noise from the nearby Waterloo Bridge Road. The 'warm frame' construction ensures a high quality internal environment.

According to the general contractor for the project, Pearce Construction, it is the largest project in the UK to be renovated using light steel framing. The overall construction value is £40 million and the complete construction programme for the three buildings was 3 years to occupancy.

Century House is the largest project in the UK to be renovated using light steel framing.

Twenty-storey Tower Block is Transformed using Light Steel Framing

Technical details

Application benefits

- Roof-top extension creates high quality apartments
- No temporary formwork or support
- Light weight does not overload existing structure
- Excellent acoustic insulation
- Minimum disruption to nearby buildings
- Efficient site process with minimum storage of materials
- Dry construction technology

Project data

Clients
Metropolitan Home Ownership and Crest Nicholson plc

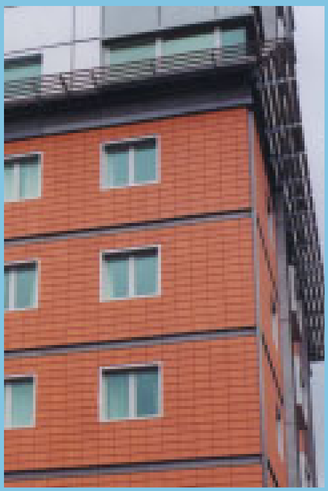
Developer
Crest Nicholson plc

Contractor
Pearce Construction

Architect
Assael Architecture Limited

Cladding
Allscot/Baris UK

Infill walls
Knauf/Metsec Framing



Terracotta panels

Entrance canopy in tubular steel

Construction details

There are three buildings in this major project, two of which posed the following challenges in their renovation and upgrading to modern standards:

- Removal of internal concrete shear walls;
- Infilling of existing service risers;
- New penthouses as a roof-top extension;
- New lightweight cladding to transform building appearance.

The existing structure consisted of hollow-core floor slabs, spanning from a spine of central service cores to spandrel edge beams. Stability was provided by shear walls and by framing action between the spandrel beams and edge columns.

Lightweight infill walls using 150 mm deep C sections were used in the renovation in order not to over-load the existing floor slab (this would not have been possible in dense concrete brickwork). Service risers were in-filled with a new composite floor slab and steel angles bolted to the existing concrete structure, which avoided the need for propping.

The new 2-storey penthouse is supported by the existing structure. It is constructed in a lightweight steel framework, using RHS sections at the perimeter of the structure to support the upper levels. Fire protection was achieved using intumescent coating to preserve the crisp shape of the RHS sections, which act as window mullions.

A lightweight metallic and terracotta tile cladding system was selected in order to create the required architectural appearance, and to be constructed rapidly without over-loading the existing spandrel beams. The same system was used on the three buildings in the project.

Over-roofing in progress

Lightweight infill walls

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The Steel Construction Institute

An innovative building concept using composite floors and light steel framing was demonstrated in this Thames-side residential building, in which there was a requirement for light weight and creation of open plan space.

Quality Apartments using New *Metframe* Flooring System

Light Steel Framing

Tunnel Wharf is one of the largest buildings constructed using *Metframe*. A lightweight structure was required to minimise the loads on Brunel's railway tunnel beneath.

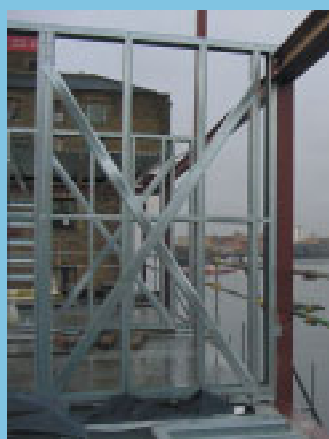
Structural engineer turned developer, Bryn Bird, wished to demonstrate his concept of a lightweight composite flooring system, developed with colleague Bernard Sanders, and turned to Metsec to realise his ideas. Tunnel Wharf in Rotherhithe, East London is the site of Bird's mixed commercial and residential development, which was made technically more demanding by the adjacent tidal Thames and Brunel's 1840's railway tunnel beneath.

The 8-storey building comprises 11 apartments and a penthouse in which the Bird family will live. The ground floor is for offices and possibly a restaurant, and below is a half basement car park. The high quality apartments range from 100 to 220 m^2 floor area in 2, 3 and 4 bed configurations.

There was a requirement for a lightweight structure to reduce the loads on the foundations, yet the super-structure was supported on a concrete transfer slab. The walls comprised pre-fabricated load-bearing panels from the *Metframe* system, with intermediate hot rolled steel beams and columns.

The innovative flooring system, *Conform*, used standard Metsec joists with a concrete topping supported by thin steel 'pans'. The advantage of this system proved to be a lightweight structure, but with floors having sufficient mass to achieve excellent acoustic insulation and robustness to impact. Spans of 6.5 m were achieved with a single temporary prop, or 5 m when unpropped. This gave the apartments a light, airy feel and, internally, the individual rooms could be easily fitted-out.

The complex curved walls and raking façades stretched the innovative design concept to the limit for this £3 million riverside development, but the end result is a lightweight building with open, adaptable space. It is one of the largest buildings constructed using *Metframe* and extends the use of light steel framing into medium-rise apartments.



Pre-fabricated wall panels

Quality Apartments using New *Metframe* Flooring System

Technical details

Light Steel Framing

Application benefits

- Robust structural system
- Fast construction for this inner city site
- Innovative flooring system
- Open adaptable space
- Good acoustic insulation
- Light weight relative to reinforced concrete

Project data

Contractor/Developer
Tunnel Wharf Developments

Architect
CZWG Architects

Structural Engineer
Alan Conisbee

Services Engineer
Max Fordham

Constructor
Ellmer Construction

Light Steel Framing
Metsec Framing

Detail of *Conform* flooring system

Construction details

The *Metframe* system consists of 150 mm C section wall studs pre-fabricated into storey high panels. The steel thickness varies from 1.6 mm at the upper floors to 3.2 mm at the heavily loaded ground floors. The '*Conform*' flooring system comprises 185 mm C section joists supporting a 120 mm deep steel 'pan' placed on the bottom flange of the joists. This 'pan' acted as permanent formwork to the thin concrete topping above it. The overall slab depth was 220 mm. Reinforcing bars were placed parallel to the joists to provide the necessary additional load resistance and fire resistance. Spans of up to 7.2 m were achieved in a prototype construction built before the project started. This project is the first example of this innovative flooring system.

Metframe uses the steel detailing package, *Strucad*, to draw, detail and fabricate the super-structure, which also included many hot rolled steel components. The raking façade on one side of the building proved to be demanding, as did the 2-storey penthouse with its curved infill panels.

External steelwork supported 4 or 5-storeys of brickwork on the south and east façades, allowing the ground floor to be fitted-out for commercial use. Elsewhere, zinc cladding was fixed to timber and was supported directly by the wall panels by screwing through the *Celotex* insulation. Steel stairs were also supplied by Metsec, which facilitated early fit-out.

The floor and wall structures achieved excellent acoustic insulation, higher than the standard of the Building Regulations. A raised floor permitted service pipes and cables to be located on the floor slab, minimising holes through the slab.

The cost breakdown for this project is consistent with the complex nature of the site and the high quality of the building.

Cost analysis

COMPONENT	COST (£ 000)	% OF TOTAL
Frame, floors, stairs	422	14
Cladding & roofing	563	19
Services (M & E)	503	17
Internal fit-out	801	26
Foundations/podium	427	14
Site preliminaries	288	10
Total	**£3,000**	**100%**

Total floor area 1,000m^2 approx.

Metframe panels during construction

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The Steel Construction Institute

This major estate regeneration project using light steel framing demonstrates a range of applications from single family houses and apartments to a 'mixed' retail and domestic street-scape.

Major Affordable Private Housing Project Underway in Basingstoke

Light Steel Framing

The use of light steel framing ensured early completion of the first phase and return on the investment, leading to reduced cash flow to the client in this major project.

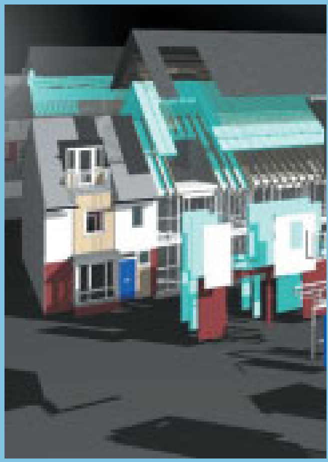
Oakfern Housing Association, part of the Sentinel Housing Group, has commissioned a 294-unit housing project in Basingstoke using light steel framing as the chosen construction system. The project consists of a mix of 55% social/45% private housing units, ranging from assisted bungalows to 4 to 8-person housing and 4-person apartments.

Architects for the project, HTA, worked closely with structural engineer Michael Barclay Partnership and contractor Walter Llewellyn Ltd to optimise design and buildability in this novel project. Forge Llewellyn Ltd was selected as the light steel framing supplier because of their experience on similar public-private housing projects, and their willingness to develop the design concept in the early stages of the project.

A strict dimensional discipline was devised in order that all bathrooms were of the same size and layout. The front-back dimensions were also fixed on all units so that house types could be linked without changes to the roof profile.

The buildings consist of eight basic house or apartment types, all in light steel framing, with some variation for corner units. Phase 1 of the development is now complete, and Phase 2 involves 'mixed use' retail and apartment buildings to re-create the traditional street-scape in modern style. The façades comprise a mixture of brickwork, render and timber. In some buildings, the roof space is utilised by means of attic roof trusses.

The project was conceived as a novel economic partnership following the 'Egan' principles between the constructor and the client. The constructor is guaranteed a fee, but the profits from the project are returned to the Association to enable the funding of infrastructure and community facilities. The project started on site in May 2001 and Phase 1 was completed in September 2002. The use of light steel framing ensured early completion of the first phase and return on the investment, leading to reduced cash flow to the client in this major project. Phase 2 is underway.



The Steel Construction Institute

Major Affordable Private Housing Project Underway in Basingstoke

Technical details

Light Steel Framing

Application benefits

- Speed of construction – early return on investment
- Reliability of construction programme
- Floors and walls installed in large panels
- Dimensional discipline
- 'Mixed' retail/domestic uses
- Good performance characteristics

Project data

Client
Oakfern, part of Sentinel Housing Group

Architect
HTA Architects

Structural Engineer
Michael Barclay Partnership

Constructor
Walter Llewellyn Ltd

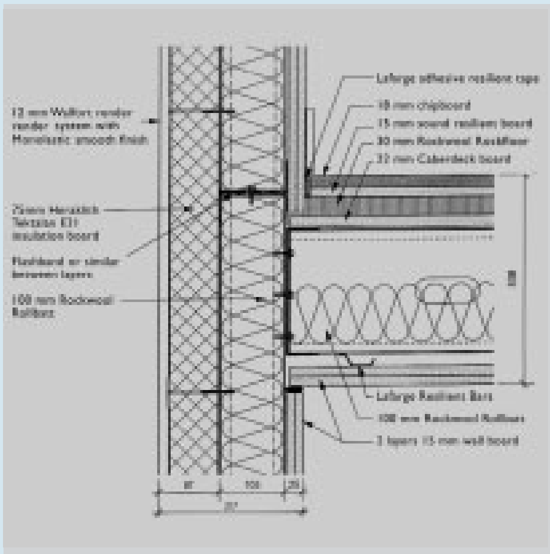
Light Steel Framing
Forge Llewellyn Ltd (now The Forge Company)

Rendered Façade
Permarock Products Ltd and George Howe Ltd

Construction details

The light steel framing consists of 100 mm C sections in the walls, and 200 mm C sections in the floors. Positions of load-bearing walls are rationalised in the house plans, and floors span up to 4.5 m. Floors were installed as large cassettes to speed up the construction process. Open attic trusses create habitable space in roofs and provide private balconies.

The houses are typically 8.2 m deep on plan and 5.2 to 5.7 m on façade. The same basic house form is used in 2 and 3-storey configurations. The apartments are different in form, with 4 apartments on each of the 3 floors. Unit sizes range from 50 m^2 for single-person flats to over 138 m^2 for 5-person houses.



Detail of rendered façade

All bathrooms and staircases are identical throughout the project, which achieves economy in production, and rationalises interfaces and dimensions. In this project, the bathrooms are fitted on site, but they could also be produced as modules that are fitted out off-site. Pre-fabricated steel stairs were installed in the apartments.

A high level of thermal insulation is provided in the external elements, leading to a U value of 0.2 W/m^2°C , much better than the value of 0.35 W/m^2°C in the Part L of the 2002 Building Regulations. Similarly, in the multi-occupancy dwellings, the 'built-up' floor and double skin walls achieve a sound reduction of over 60 dB, which is better than Part E of the Regulations. The rendered façade was installed on insulation attached directly to marine grade plywood screwed to the light steel frame.

Light steel floor joists showing attachment to wall

Artist's impression of apartments

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The Steel Construction Institute

Mixed modular and light steel framing were used in this hotel project which was designed to meet strict performance requirements next to Heathrow Airport. The same technology is being used on other hotel and residential projects.

Light Steel Framing for Heathrow Hotel

Light Steel Framing

Light steel framing has speed of construction and weight advantages over masonry or pre-cast concrete and can accommodate concrete upper floors for better acoustic performance.

The benefits of building up to 25% faster than traditional methods, plus ease of installation and high performance has led to major hotel developers awarding £3.5 million worth of contracts for Metsec Framing's fast-track light steel framed structures.

The largest of the contracts is the 4-storey, 230-bed Holiday Inn Core Brand hotel at Heathrow Airport, an Alfred McAlpine Special Projects contract for BDL Hotels. *Metframe* was chosen over its main competitor, pre-cast concrete, because its light weight reduced the craneage requirements on a long, narrow site. Masonry was ruled out as being too labour-intensive.

The £1.9 million *Metframe* package includes designing, fabricating/supplying and installing the light steel super-structure, internal walls, profiled steel decking for the concrete floors, staircases and drylining, plus installation of the complex roof structure and bathroom pods.

The building shell is supplied as pre-fabricated wall panels fitted with rigid insulation board on the outside. Internal walls are loadbearing steel studs, packed with insulation quilt and drylined to meet strict fire resistance and acoustic performance specifications.

Special features include an additional layer of insulation quilt within the *Metframe* steel stud external wall panels to provide an extra acoustic buffer against noise from the nearby Heathrow Airport. Unusually, the 3 and 4-storey structure is built on a concrete podium which forms the ground floor of the hotel and accommodates bars, restaurants etc. The hotel is split into three pavilions providing 9,224 sq m of floor space. The building was completed in 65 weeks and reached its dry envelope stage within 22 weeks of the light steel framing starting on site.

Metframe super-structures have been used in 15 hotels in the last two years because light steel framing has speed and weight advantages over masonry or pre-cast concrete. Compared with timber framing, it has the benefit of giving a more ‘solid’ feel to the building and can accommodate concrete upper floors for better acoustic performance.


Ground floor concrete podium

The Steel Construction Institute

Light Steel Framing for Heathrow Hotel

Technical details

Application benefits

- Speed of construction to meet tight programme.
- Bathroom pods improves installation of services.
- Excellent acoustic insulation to external noise.
- Robustness (five storeys height)
- Good performance in service

Project data

Client
Holiday Inn

Architect
Young and Gault

Main Contractor
Alfred McAlpine Special Projects

Light Steel Framing
Metsec Steel Framing / Walker Group

Internal framing supporting composite decking

Construction details

The *Metframe* system consists of 100 mm stud walls which are pre-fabricated and bolted to the other wall panels and floors. Steel decking acts as permanent formwork to the in-situ concrete slab, and the composite floor slab that is created is very stiff. Additional layers attached to the floor slab and walls provide the necessary acoustic insulation. For this project, the external wall panels are insulated against potentially high levels of noise from the nearby Heathrow Airport.

The building is three and four storeys high, and has a basement. It is designed to comply with the Building Regulations requirements for progressive collapse, which is achieved through the bolted connections. The upper four floors are supported on a ring beam as part of the *Metframe* system.

The toilet/bedrooms are installed as pre-fabricated pods or modules, which speeds up the servicing of the hotel. *Metframe* also supplied the stair units, the complex roof structure, decking, and drylining, as a comprehensive package to the main contractor. The same system is used on other major hotel projects.

Cost analysis for typical hotel project

Floor area: 2,600 m²; 78 rooms

ELEMENT	£/m²
Sub-structure	42
Light steel frame	62
Floors (decking and concrete)	47
Roof	27
Stairs	10
External walls	77
Other items	525
Total construction cost	**£790/m²**

Source: Building, 10 October 1999

Room modules before cladding

Delivery of toilet/bedroom pods

Toilet/bedroom pods in place

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