SCI Steel Knowledge

Technical Information Sheet ED014

Light Steel Modular Construction

R M Lawson BSc PhD CEng MICE MIStructE MASCE ACGI

This Information Sheet reviews the various forms of building modules constructed using light steel framing and presents examples of where modular construction has been used. It reviews the basic principles of design using modular construction and addresses the basic dimensions, design requirements and interfaces with cladding, services and other details.

Key benefits

The benefits of modular construction are:

- Economy of scale by manufacture of multiple similar modular units.
- Speed of construction, which is up to 50% faster than traditional methods.
- High level of quality control through off-site manufacture.
- Minimum disturbance to the locality during construction.
- Detailed design work is carried out by the modular supplier.
- Suitable where site constraints may limit deliveries needed for other more traditional methods of building.
- Elimination of on-site waste; waste in the factory can be recycled more easily.
- Suitability for roof-top extensions in building renovation.
- Specialist equipment and services may be commissioned and tested in the factory, which is important in hospital projects.
- Modules may be moved in the future as demand changes.

Modular construction

The use of modular and other lightweight forms of building construction is increasing. The benefits of off-site prefabrication and improved quality in manufacture are being realised for residential buildings, for mixed use projects (e.g. commercial with housing), educational and health sector buildings.

The various design issues related to compliance with the Building Regulations, including structural design, acoustic and thermal insulation, are presented in detail in the SCI publication: *Residential Buildings using Modular Construction* (P302).

The main sectors of application of modular construction are:

- Private and social housing
- Apartments and mixed use buildings
- Educational sector and student residences
- Key worker accommodation and sheltered housing
- Public sector buildings, such as prisons and MoD buildings
- Health sector buildings
- Hotels.

High-rise modular building, London
(Image courtesy of Futureform and Ayrshire Framing)

Three storey modular office building
(Image courtesy of BW Industries)

Modular residential building
(Image courtesy of Lightspeed Construction Ltd)

Four Sided Modules

Form of construction

Four-sided modules are manufactured with four closed sides to create cellular type spaces and are designed to transfer loads through their longitudinal walls.

The modules are designed for the combined vertical load from the modules above and in-plane loads due to wind action. The maximum height of buildings in four-sided modular construction is typically 6 to10 storeys, depending on location and exposure to wind loading. However, taller buildings can be achieved when modules are combined with a concrete or steel core.

Application

Cellular buildings, such as hotels, student residences, residential buildings and key worker accommodation.

Technical details

Modules are manufactured from a series of 2D panels, beginning with the floor cassette, to which the four wall panels and ceiling panel are attached. The walls transfer vertical loads and therefore the longitudinal walls of the upper module are designed to sit on the walls of the module below.

An example of a four-sided module is illustrated in Figure 1.

Modules are essentially four sided volumetric units with openings in their ends for windows and doors. Their external width is limited by transportation requirements to approximately 4 m (3 to 3.6 m is the typical internal module width for most applications). The module length is typically 6 to 15 m. The light steel walls typically use 65 to 100 mm deep C sections.

The maximum height of a modular building is generally limited by the compression resistance of the members in the walls and by the bracing in the walls. Additional steel angle members may be introduced in the corners of the modules for lifting.

The floor joists are typically 150 or 200 mm deep, and the combined floor and ceiling depth is in the range of 300 to 450 mm.

Figure 1 Four sided module (with staggered end)
(Image courtesy of Ayrshire Framing)

Bracing and lateral stability

The bracing system required generally depends on the geometric form of the building. Various solutions are used:

- For low rise buildings, in plane bracing or diaphragm action of the board materials within the modules can be sufficient.
- For buildings of 6 to 10 storeys height, a vertical bracing system is often located around an access core, and assisted by horizontal bracing in the corridor floor between the modules.
- For taller buildings, a primary steel podium frame may be provided on which the modules are stacked and supplemented by a concrete or steel core.

Figure 2 Long four-sided module with an integral corridor
(Image courtesy of Kingspan)

Partially Open-Sided Modules

Form of construction

Modules can be designed with partially open sides by the introduction of corner and intermediate posts and by using a stiff edge beam in the floor cassette. Additional intermediate posts are usually square hollow sections of small cross-section, so that they can fit within the wall.

Two modules can be placed together to create wider spaces. The compression resistance of the corner or internal post is critical in the structural design. Typically, 6 to 10 storeys can be achieved, as for four-sided modular construction.

Long modules can also be designed to include an integral corridor, as shown in Figure 2. This approach can avoid weather tightness problems during installation and finishing work.

Application

Key worker accommodation, small apartments, hotels with corridors, communal areas in student residences.

Figure 3 Partially open sided modules
(Image courtesy of Futureform and Ayrshire Framing)

Technical Details

Details are similar to four sided modules, except for the use of additional posts, generally in the form of 70 × 70 to 100 × 100 SHS steel members.

Overall stability and transfer of horizontal forces is provided by additional bracing located in the walls of the modules. Balconies or other components can be attached to the corner or internal posts.

The edge beams in the floor cassette can be designed to span 2 to 3 m to create openings in the sides or ends of the module. An example of the arrangement of partially and fully open-sided modules in a school building is shown in Figure 4.

Stability of the modules is affected by their partially open sides; additional temporary restraints may be necessary during transport and installation.

A separate bracing system may also be required, as the partially open-sided modules may not possess sufficient shear resistance in certain applications.

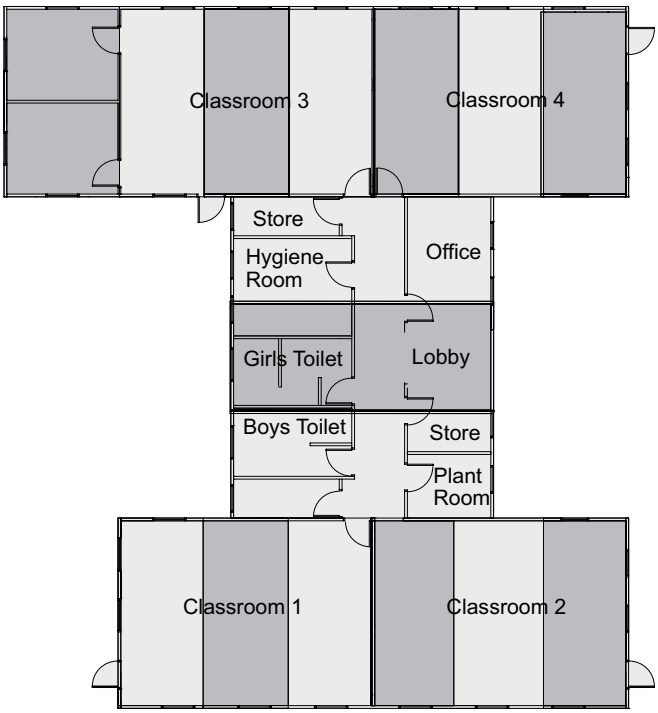

Figure 4 Layout of school building using partially and fully open sided modules (alternate modules are shown shaded)
(Image courtesy of BW Industries)

Open-Sided (Corner Supported) Modules

Form of construction

Modules may be designed to be fully open on one or both long sides by transfer of loads to the corner posts. This is achieved by bending of the longitudinal edge beams. The framework of the module often uses Square Hollow Section (SHS) columns and Parallel Flange Channel (PFC) edge beams that are bolted together.

Modules can be placed side by side to create larger open plan spaces, as required in hospitals and schools etc. The stability of the building generally relies on a separate bracing system (usually of X bracing) in the separating walls. For this reason, fully open sided modules are not often used for buildings more than three storeys high.

Application

Schools and hospitals in low-rise buildings. Residential buildings with variable room sizes.

Figure 5 Demonstration modular hospital ward building (with perspex wall to show construction)
(Image courtesy of BW Industries)

Technical details

Open-sided modules comprise a primary steel framework with longitudinal edge beams supporting the floor joists. Edge beams are typically 300 to 450 mm deep, depending on the span, which typically is 5 to 8 m. Some systems use heavy cold-formed sections, and others use hot rolled steel sections, such as PFC. The combined depth of the edge beams, the ceiling and floor may be 600 to 800 mm.

Design flexibility is provided by the open-sided modules. Their width is typically 3 to 3.6 m, and rooms of 6 to 12 m width can be created by combining modules.

The corner posts provide the compression resistance and are typically 70 × 70 to 100 × 100 SHS. The edge beams may be connected to these posts by fin plates, which provide nominal bending resistance. The corner posts possess sufficient compression resistance for use in buildings up to 10 storeys.

As open sided modules are only stable on their own for one or two storeys, additional bracing is usually introduced vertically and horizontally. In plane forces can be transferred by the floor and ceiling cassettes and by suitable connections at the corners of the modules.

Typical details of the internal framework of an open sided module using PFC beams and SHS posts are shown in Figure 6. Installation of open sided modules in a hospital building is shown in Figure 7.

Modules using a hot-rolled steel framework can be designed to support concrete floors for use in medical and other applications, where strict control of vibrations is required.

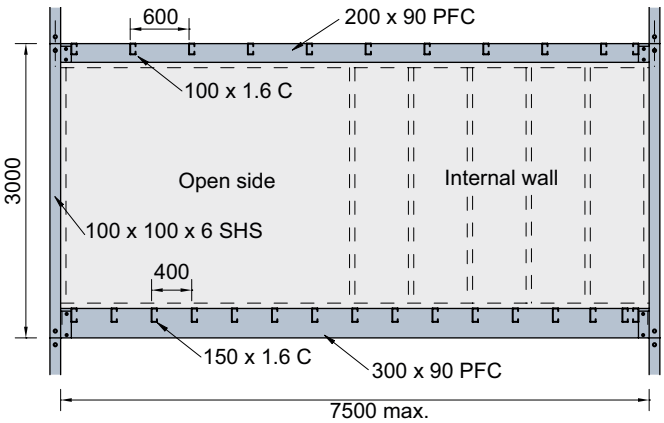

Figure 6 Longitudinal edge beams of an open-sided (corner supported) module

Figure 7 Installation of open sided modules for a hospital
(Image courtesy of Yorkon)

Modules Supported by a Primary Structure

Form of construction

Modular units may be designed to be supported by a primary structure at a podium level. The supporting columns are positioned at a multiple of the width of the modules (normally 6 to 8 m). The beams are designed to support the combined loads of the modules above.

The supporting steel structure provides open plan space at ground floor and below ground levels.

An external steel structure, consisting of a façade structure that acts to stabilise the building, may also be used. Modules are placed internally within the braced steel 'exo skeleton', as shown in Figure 9.

Stability of a tall modular building can also be provided by clustering the modules around a concrete core, as shown in Figure 10. The modules are designed to resist only vertical load.

Application

This form of construction is suitable for mixed retail, commercial and residential developments. Modules can be set back from the façade line. A mixed development with commercial space at ground floor is shown in Figure 8.

Modular units may be supported by a hot-rolled steel or concrete podium structure. Buildings with podiums are typically mixed-use, with residential units above commercial areas or car parking.

Figure 8 Podium structure used to support residential modular units
(Image courtesy of The Design Buro and Ayrshire Framing)

Technical details

Modules can be designed to be supported by steel or composite beams. Columns generally align with every 2 or 3 modules. The depth of the podium type structure is typically 800 to 1000 mm, and spans of 10 to 18 m can be created below the podium.

Figure 9 Installation of modules behind external steel framework at MoHo, Manchester
(Image courtesy of Yorkon and Joule Consulting Engineers)

Figure 10 Concrete core used to stabilise 16 storeys of modules
(Image courtesy of Futureform and Ayrshire Framing)

The use of a concrete core requires that the modules are tied into the core by cast-in plates and welded or bolted connectors to the corridors, which are designed as a horizontal wind girder. This may be in the form of cross bracing of the corridor floor panels, or for longer corridors, a separate lattice structure.

Other Types of Modules

Stair modules

Stairs may be designed as fully modular units. They generally comprise landings and half landings with two flights of stairs. The landings and half landings are supported by longitudinal walls, with additional angles or square hollow section members to provide local strengthening, if necessary.

Application

Stair modules may be used in buildings using fully modular construction up to four storeys in height.

Technical details

For their stability, stair modules rely on a base and a top, which leads to use of a false landing. The walls may require additional strengthening members at the half and full landing positions. The stairs can be fully or partially finished before delivery to site. SHS columns and bracing can be introduced in the walls to provide stability.

A typical light steel modular stair system is shown in Figure 11. False landings or lateral sections are required to provide stability at the roof of the module.

Alternatively, the framework of the stair module may be made as a primary steel structure, in which case, the light steel walls act as infill.

Figure 11 Light steel modular stair system
(Image courtesy of Ayrshire Framing)

Non-load bearing modules

Non-load bearing modules (or pods) are of similar form to structural modular units, but are not designed to resist loads, other than their own weight and the forces exerted during lifting. They are supported directly on a floor or by a separate structure, and are designed to be installed either as the construction proceeds or slid into place on the completed floor.

Application

Toilet/bathroom units, plant rooms, other serviced units.

Technical details

The structure of a non-load bearing module is lighter than in structural modular construction, but it must still be sufficiently rigid to resist the forces during lifting and installation. The walls and floor of these pods are relatively thin (typically less than 100 mm). An example of a bathroom pod used in a light steel structure is shown in Figure 12.

Figure 12 Toilet pod used with light steel framing in a hotel
(Image courtesy of Metek UK)

Compatibility of the floor depth in the module and in the floor elsewhere is achieved by one of four methods:

- Designing the depth of the floor of the module to be the same as the acoustic layer elsewhere.
- Placing the module in a recess in the floor of the main structure.
- Designing the module without a floor (possible in small modules by attaching fitments to the walls).
- Designing the modules to be supported on the bottom flange of Slimflor beams.

Technical Solutions

Stability and structural integrity

Lateral stability can be provided by the modules themselves, or by an external structure. Robustness is provided by the ties between the modules; a minimum tying resistance equal to at least half the loaded weight of the module is recommended (minimum value of 30 kN). Module to-module connections are usually in the form of plates that are bolted together on site.

Cladding

Various forms of cladding may be used, such as:

- Brickwork
- Metallic fascia
- Insulated render
- Board materials.

Lightweight cladding can be pre attached to the modules to eliminate the requirement for scaffolding.

Acoustic performance

The double layers of floor and ceiling, and separating walls, as shown in Figure 13, achieve excellent airborne and impact sound insulation. Airborne sound reductions of over 52 dB (with low frequency correction factor), are achieved, which are up 5 to 10 dB better than required by Part E of the Building Regulations. Impact sound transmissions are also low (< 30 dB).

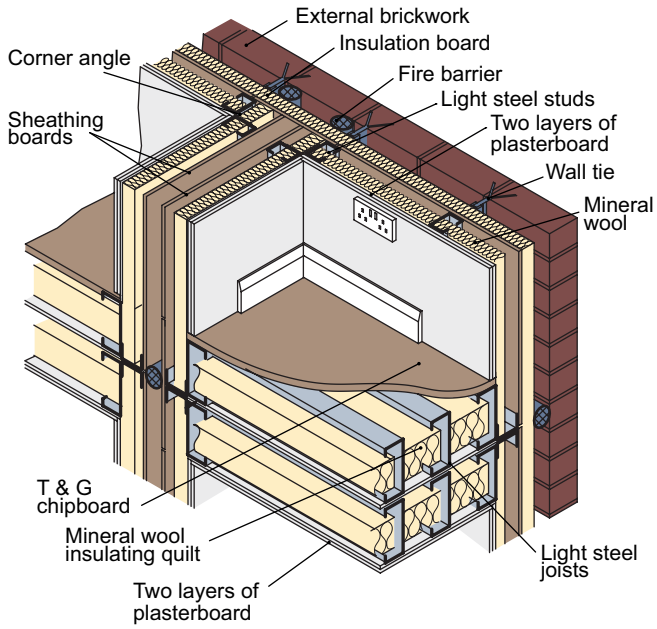

Figure 13 View of floor and wall in modular construction showing fire protection and cavity barriers

Thermal insulation

Thermal insulation is characterised by the heat loss per unit area of façade (i.e. U value). Low U values of less than 0.2 W/m^2 °C and excellent air tightness can be achieved.

Services

Services are usually pre-installed within the module and service attachments are made externally to the modules, usually in the corridor zone. The modules can be constructed with a recessed corner zone for vertical service routing, or a separate service zone may be constructed outside the module.

Fire resistance

Fire resistance is provided by multiple layers of fire resisting boards (Type F to BS EN 520). Two 15 mm thick fire resisting plasterboard layers internally plus 100 mm thick mineral wool can achieve a fire resistance of 90 minutes. Outer sheathing boards also assist in preventing passage of smoke into the modules. Regular fire cavity barriers in the form of mineral wool 'socks' are provided horizontally and vertically, as in Figure 13.

Balconies

Balconies may be attached to modules in various ways:

- Balconies supported by a self standing steel structure that is ground supported
- Balconies attached between adjacent modules
- Balconies attached to corner posts in the modules
- Integrated balconies within open-sided modules.

Figure 14 Raines Court, London showing modular construction with integral balconies
(Image courtesy of Alford Hall Monaghan Morris and Yorkon)

Sources of Information

Other technical information sheets

The following technical information sheets provide further guidance about light steel construction.

- ED010: Light Steel Solutions for All Applications
- ED011: Light Steel Residential Buildings
- ED012: Light Steel Framed Housing
- ED013: Light Steel Infill Walls
- ED015: Acoustic Performance of Light Steel Construction
- ED016: Fire Safety of Light Steel Construction

Manufacturers

The following manufacturers are active in the light steel and modular construction sector and may be contacted for further information.

Ayrshire Metal Products Ltd - www.ayrshire.co.uk

BW Industries Ltd - www.bw-industries.co.uk

Fusion Building Systems - www.fusionbuild.com

Kingspan Profiles & Sections - www.kingspanprofiles.com

Metek UK Ltd - www.metek.co.uk

Figure 15 Light steel energy efficient housing constructed using modules
(Image courtesy of Ayshire Metal and Futureform)

Bibliography

The following publications may be referred to for more information on design in modular construction.

Modular construction using light steel framing: Residential buildings (P302)
Gorgolewski M T, Grubb P J and Lawson R M
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SCI Steel Knowledge

The Steel Construction Institute
Silwood Park, Ascot
SL5 7QN

T: 01344 636525
F: 01344 636370

E: publications@steel-sci.com
www.steel-sci.com

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