

Technical Information Sheet ED021

Robustness of Light Steel Construction

Achieving structural robustness is an important aspect of the design process, particularly for multi-storey buildings for which light steel framing or modular construction is a popular solution. Designing for robustness is an integral part of the design process whether the Eurocodes or the former British Standards are used. Designing for robustness is also a specific requirement within the Building Regulations.

Key benefits

The benefits of light steel framing and modular construction in relation to structural robustness are:

- Light steel framing and modular construction provide robust structures that satisfy the Building Regulation requirement for avoidance of disproportionate collapse.
- Robustness is provided by multiple members with a high degree of inter-connectivity.
- Load bearing walls are produced that distribute loads rather than relying on discrete load bearing columns.
- Light steel frame construction generally has lateral bracing distributed throughout the structure.
- The form of construction creates multiple load paths which mean loads can be transferred around areas of local damage.
- Light steel structures are capable of resisting high wind loads.
- Modular construction can be designed so that complete modules can be removed without the building becoming unstable.
- Light steel buildings are commonly used in seismic zones with a good record for surviving earthquakes and flooding.
- The lightweight nature of the construction means that if any local damage does occur, debris loading is considerably less compared to heavier construction materials.
- Steel is a ductile material which is able to sustain significant deformation without detrimental loss of strength.

Robustness terminology

The terminology relating to structural robustness can be confusing as different terms are used in different documents. The former British Standard for cold formed sections (BS 5950-5) uses “structural integrity”, Eurocode 1 Part 1.7 uses “robustness” and the Building Regulations use “avoidance of disproportionate collapse”. The objective is similar with all these documents and is encapsulated by the definition of robustness provided in BS EN 1991-1-7; “*Robustness is the ability of a structure to withstand events like fire, explosions, impact or the consequences of human error, without being damaged to an extent disproportionate to the original cause*”.

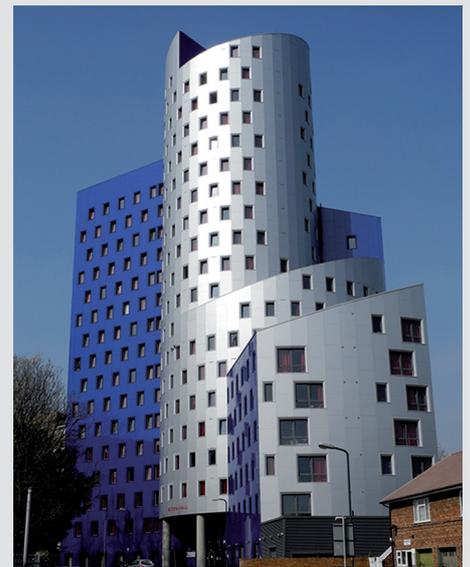
Detailed guidance on general aspects of robustness is provided in SCI publication: *Structural Robustness of Steel Framed Buildings* (SCI-P391).

A G J Way MEng CEng MICE



Six storey light steel frame accommodation in London

(Image courtesy of Fusion Building Systems)



High rise modular residential building

(Image courtesy of Ayrshire Framing and Futureform)



Class 2b hospital development in Devon

(Image courtesy of Kingspan Steel Building Solutions)

Designing for Robustness

Regulations and design standards

The Building Regulations require that buildings are designed for the avoidance of disproportionate collapse. Approved Document A gives guidance on how this is achieved. The guidance is generally that the structural design should be carried out in accordance with an appropriate design standard.

BS 5950-5, *Structural use of steelwork in building. Part 5: Code of practice for design of cold formed thin gauge sections*, includes specific rules for light steel frame buildings. These rules are based on the guidance presented in SCI publication P301, which was formulated from research carried out by SCI in the 1990s. BS 5950-5 was withdrawn in 2010 but is still a source of authoritative guidance.

BS EN 1991-1-7, *Eurocode 1: Actions on structures - Part 1-7: General actions – Accidental actions*, presents generic robustness rules for all forms of construction and does not provide specific rules for light steel frame buildings. However, the UK National Annex to BS EN 1991-1-7 does present additional guidance for lightweight construction.

UK National Annex clause NA.3.1 states that: *“In the case of lightweight building structures (e.g. those whose primary structure is timber or cold formed thin gauge steel) the values for minimum horizontal tie forces in expressions A.1 and A.2 should be taken as 15 kN and 7.5 kN respectively”*. This is in line with the guidance given in BS 5950-5 and represents a significant reduction from the minimum tie force of 75 kN required for other forms of construction.

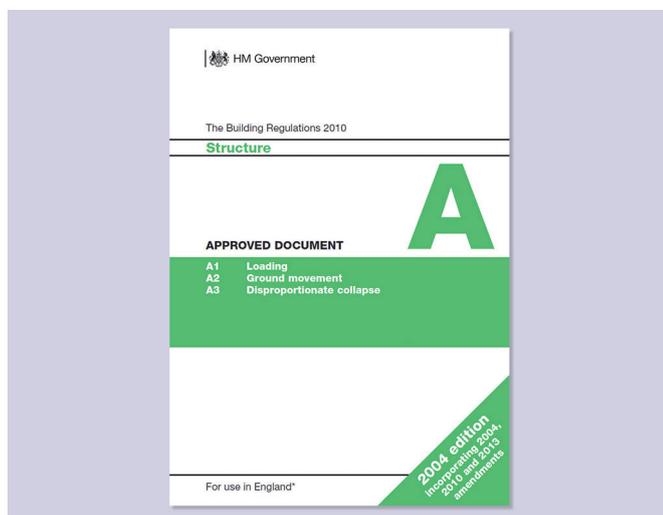


Figure 1 Approved Document A for England and Wales Building Regulations

Building classes

The required level of robustness depends on the classification of the building, which is determined from its use and size. There are four classes of building; Class 1, Class 2A, Class 2B and Class 3. The robustness requirements are progressively more stringent from Class 1 to Class 3, which reflects the increased severity of the consequences associated with an accidental event.

BUILDING CLASS	EXAMPLE BUILDINGS
Class 1	Single family houses not exceeding 4 storeys.
Class 2A	5 storey single family occupancy houses. Hotels not exceeding 4 storeys. Flats, apartments and other residential buildings not exceeding 4 storeys. Offices not exceeding 4 storeys.
Class 2B	Residential buildings (hotels, flats, apartments) and offices greater than 4 storeys but not exceeding 15 storeys.
Class 3	Residential buildings (hotels, flats, apartments) and offices greater than 15 storeys.

Table 1 Building classifications

Robustness requirements

The following robustness requirements are taken from BS EN 1991-1-7.

- Class 1 buildings – There are no additional robustness requirements if the structure is designed to BS EN 1993.
- Class 2A buildings – Horizontal ties must be provided.
- Class 2B buildings – There are three alternative approaches that can be adopted; tying, notional removal, or key element design. For the tying method, which is the most common approach for light steel framing, horizontal and vertical ties must be provided. It is also recommended that bracing systems are distributed throughout the structure and if heavy floor units are used they should be suitably anchored.
- Class 3 buildings – A systematic risk assessment must be carried out. It is also recommended that the robustness requirements for Class 2B buildings are applied.

Technical Guidance

Horizontal ties

Horizontal ties should be provided in two orthogonal directions. One set of horizontal ties will generally be formed from the head track of the supporting wall below or a zed section used to support the floor joists. The floor joists themselves should be designed as the ties in the second direction. In each case the element and its end connections should be designed for the required tie force.



Figure 2 Connection of floor joist to supporting zed section
(Image courtesy of BW Industries)

Formulae to calculate the required tie forces for different types of tie member are presented in SCI publication P402. These formulae are based on Equations A.1 and A.2 from EN 1991-1-7 adjusted to account for the UK National Annex requirement for lightweight structures.

Vertical ties

All splices in primary vertical elements and connections between vertically adjacent wall panels should be capable of resisting a tensile force equal to the largest design vertical permanent and variable load reaction applied to the column (or wall) from any one storey. Wall panels are typically screwed or bolted through the base track to the wall panel below to satisfy the vertical tying requirement.

Notional removal

Tying is the most common robustness solution for light steel framing. However, if the conditions for the tying method are not met, the designer should check each storey to ensure that disproportionate collapse would not be precipitated by the notional removal of vertical load-bearing elements, considered one at a time.

For panel structures, such as light steel framing, notional removal requires consideration of the notional removal of a wall panel of 2.25 times the storey height.

Key element design

If the notional removal of a vertical load-bearing element would risk the collapse of an area greater than the allowable limit, then that vertical load-bearing element should be designed as a key element.

Plasterboard cannot be assumed to still be intact after an accidental event. Therefore, lateral restraint provided by the plasterboard should be discounted for key element design.

Local damage to light steel structures is easily repairable after extreme events such as flooding.

Robustness for modular buildings

Robustness for modular buildings is provided by the ties between the modules; tying action when one module is notionally removed is illustrated in Figure 4. A minimum tying force equivalent to half the loaded weight of the module is typically assumed; a minimum tie force of 30 kN is recommended.

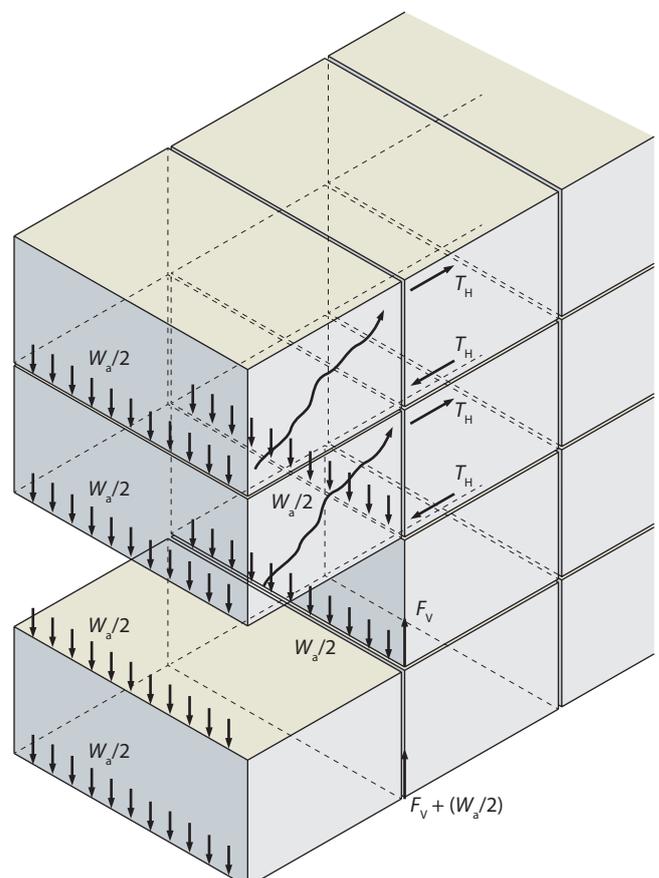


Figure 3 Tying forces in modular construction subject to notional removal of one module

Sources of Information



Figure 4 Vertical bracing in a multi-storey light steel frame building

(Image courtesy of Metek UK)

Bibliography

The following publications may be referred to for more information on robustness and light steel construction.

Lawson, R. M., Way, A. G. J. and Yandzio, E.
Building design using cold formed steel sections: Residential buildings (P402)
The Steel Construction Institute, 2014

Way, A. G. J.
Structural Robustness of Steel Framed Buildings (P391)
The Steel Construction Institute, 2011

BS 5950-5: 1998
Structural use of steelwork in building - Code of practice for design of cold formed thin gauge sections.
BSI, 2006 (Withdrawn)

BS EN 1991-1-7: 2006
Eurocode 1. Actions on structures, Accidental Actions.
BSI, 2006

UK National Annex to Eurocode 1. Actions on structures, Accidental actions.
BSI, 2008

Approved Document A.
The Building Regulations 2010. Structure.
The Stationery Office, 2013

Other technical information sheets

The following technical information sheets give further details.

- ED010: Light Steel Solutions for All Applications
- ED011: Light Steel Residential Buildings
- ED012: Light Steel Framed Housing
- ED013: Light Steel Infill Walls
- ED014: Light Steel Modular construction
- ED015: Acoustic Performance of Light Steel Construction
- ED016: Fire Safety of Light Steel Construction
- ED019: Thermal Performance of Light Steel Construction
- ED020: Sustainability of Light Steel Construction
- ED022: Durability 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 Steel Building Solutions -
www.kingspanpanels.com

Metek UK Ltd. - www.metek.co.uk



The Steel Construction Institute
Silwood Park, Ascot
SL5 7QN

T: 01344 636525
F: 01344 636370

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

www.steelbiz.org - 24x7 online technical information

www.lightsteelforum.co.uk - Light Steel Forum

ED021: Robustness of Light Steel Construction

© 2014, The Steel Construction Institute