Fire resistance of light steel framing

Mark Lawson and Andrew Way of the Steel Construction Institute (SCI) discuss issues related to fire resistance of light steel framed buildings and introduce new guidance recently published by SCI.

Since the Grenfell fire disaster, the question of the fire safety of medium- and high-rise residential buildings has been heightened. Clients and checking authorities are understandably concerned about fire safety, particularly for buildings that exceed 18 m in height, and Regulations have been introduced to prevent the use of combustible materials in external walls. SCI has been working with members of the Light Steel Forum and other industry experts to update design guidance on the fire resistance of light steel framing, which is well established as a construction system for medium-rise residential and mixed-use buildings.

Steel has well-known properties at elevated temperatures and comprehensive design data is presented in BS EN 1993-1-2 and formerly in BS 5950-8 (dating from 1990). BS 5950-8 was the first fire engineering code worldwide and it influenced Eurocode developments. The critical temperature of structural steel beams and columns is taken as 550°C for the design of the fire protection to these members and this critical temperature increases as the proportionate loading (known as the load ratio) on the member reduces. Structural engineers are familiar with the design approach for structural steel but the application of methods for cold

Figure 1: Typical application of light steel loaded walls supporting a joisted floor

Figure 2: Light steel frame construction with metal decking for composite floors

formed steel is the subject of the recent work by SCI.

Light steel framing has gained a market share because one of its benefits is that it is non-combustible and does not add to the fire load of the building. It may be used with joisted floors (Figure 1) or increasingly, with composite floor slabs that are supported by light steel load-bearing walls, as shown in Figure 2.

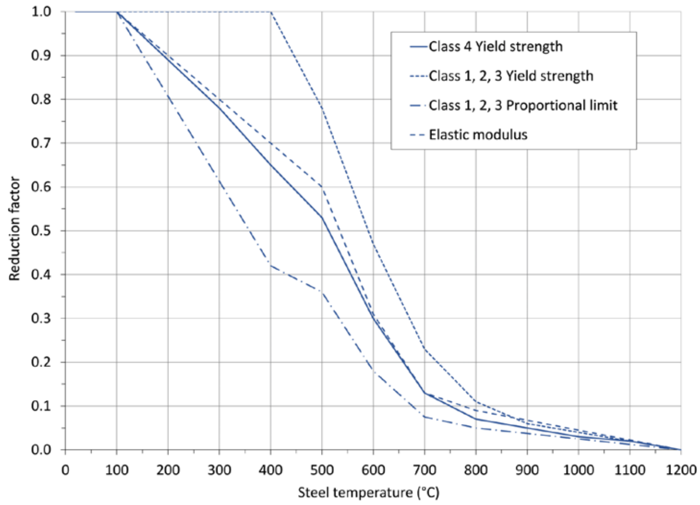

Figure 3: Strength and stiffness reduction factors for steel at elevated temperature

Strength retention of cold formed steel

Cold formed steel has slightly reduced strength retention properties at elevated temperatures compared to structural steel I and H sections and hollow sections because of the influence of local buckling of its thin profile. Nevertheless, the strength reduction factor (SRF) for Class 4 light steel sections at 550°C is still 0.41 of the nominal yield strength, as seen in Figure 3. This reduction in strength is broadly consistent with the reduction in load level at the fire limit state, which means a structure designed in the normal way at ambient temperatures is likely to be able to resist the reduced loads of the fire limit state.

Light steel framing differs from structural steel in that it is a planar construction system. The 2D walls and floors are protected by layers of Type F or similar fire-rated plasterboards. In the last 3 years, an unprecedented number of loaded fire tests have been performed by light steel framing and plasterboard suppliers to satisfy 60, 90 and 120-minutes fire resistance requirements for loaded walls and floors.

A fire test on a loaded wall (Figure 4) is generally performed using the thinnest steel section in a range with the highest sensible load that can be applied by the test house. Temperatures are measured on the flanges and web on the ‘C’ sections at a number of positions, so that the critical temperatures can be related directly to the load that is applied for the particular wall build-up. This is the so-called ‘load ratio’ method.

With this test information, the design of a ‘C’ section with thicker steel or with a different wall height to that tested can be calculated using the method developed by SCI. The only issue that affects the design solution is then the effect of non-uniform heating through the ‘C’ section for fire on one side,

Figure 4: Typical fire test arrangements for light steel loaded wall

which has two opposing effects: it causes some thermal bowing which adds to bending effects (or P-Δ effects); but on the beneficial side, the centre of resistance of the 'C' section moves towards the cooler unexposed flange. Although the two effects generally cancel each other for the normal range of wall lengths, both effects are taken into account in the design process.

Design Methodology for Loaded Walls

The formula that links the design resistance of a loaded 'C' section in a planar wall at the fire limit state to its buckling resistance in normal conditions is given by:

$$N_{b,Rd,fi} = k_1 N_{b,Rd} SRF(\theta_{ref})$$

$N_{b,Rd,fi}$	is the axial load that may be supported in fire.
$N_{b,Rd}$	is the buckling resistance of the 'C' section in normal conditions taking account of the effective length.
$SRF(\theta_{ref})$	is the strength reduction factor for a Class 4 cold formed steel section.
θ_{ref}	is the reference steel temperature for a non-uniformly heated section.
k_1	is a coefficient that takes account of thermal bowing effects and is typically 0.8 for walls supporting joisted floors or 0.9 for walls supporting composite (concrete) floors due to the greater restraint provided by the stiffer floor.

The procedure uses measured temperatures in a test and so it is important that this data is obtained as temperature versus time in order to be able to back-analyse the test. It is a pre-requisite that a valid test result is obtained for the particular wall build-up before the calculation method may be used.

The complete design guidance is presented in a new SCI publication P424. The guide includes numerical design examples and a wealth of construction details for walls, roofs, ceilings and junctions between elements.

External Fires on Loaded Walls

The same approach may be applied to external walls, although there are uncertainties about the severity of an external fire. At present, there is no agreement on this as logically it should be less severe than a fully developed fire within a compartment in a building. The approaches that have been proposed for an external fire are:

- A fully developed ISO fire curve, but with a cut-off temperature of 680°C as permitted by BS EN 1363-2 for external walls. With this limit, the fire endurance will be increased relative to an equivalent internal wall, but this test is rarely performed.
- A fully developed ISO fire curve, but with compliance for an external wall taken as a notional fire resistance of 60 minutes or alternatively the fire resistance period for the internal structure, reduced by 30 minutes. This is a simple way of recognising that a natural fire occurring outside a building or emanating from windows and radiating back onto the external wall has a lower effect than a fully developed fire internally, assuming adequate fire stopping around windows etc.
- A fully developed ISO fire curve without any reduction.

The external sheathing boards that are used are very robust structurally but do not necessarily possess the inherent insulation characteristics of gypsum-based plasterboard. Furthermore, for buildings more than 18 m high (currently for England), non-combustible insulation and sheathing boards are required.

Figure 5: Typical fire test arrangements for a light steel loaded floor

Composite floor slabs

Composite floor slabs can provide up to 120 minutes fire resistance without requiring a fire protected ceiling by virtue of the embedded reinforcing bars in the deck ribs. Guidance on the fire resistance of composite slabs is given in BS EN 1994-1-2 and in the former BS 5950-8, and SCI publication P375 - *Fire Resistance Design of Steel Framed Buildings*.

Design Methodology for Loaded Floors

Loaded floors differ from loaded walls in that the effects of thermal bowing do not add to the applied moments and the critical temperature is taken as the bottom flange temperature. Also, for floors, the plasterboard ceilings can become detached as they weaken in fire. The design approach for loaded floors is based on a similar approach to walls but a constant coefficient of 0.6 is used and the buckling resistance can take account of the restraint offered by the floor boarding, as follows:

$$N_{c,Rd,fi} = 0.6 N_{b,Rd} SRF(\theta_{exposed})$$

Most joisted floors (shown before a fire test in Figure 5) are designed for serviceability limits of deflection; their load ratio will generally be less than 0.4, meaning their performance at the fire limit state is likely to be satisfactory.

Conclusions

The new SCI publication presents detailed design guidance for light steel framing at the fire limit state. Fire tests are required, with the data used to extend the range of application to different steel thickness, size, loading and span. The publication has been circulated to SCI members; it may be downloaded from Steelbiz. ■