Hybrid Systems in Light Steel and Modular Construction

R M Lawson(1)
University of Surrey
SCI Professor of Construction Systems
Department of Engineering, Guildford, GU2 7XH, UK
m.lawson@steel-sci.com

R G Ogden(2)
Oxford Brookes University
Director of Technology, School of Architecture,
Oxford OX3 8JR, UK

KEYWORDS
Light steel; housing; modular; acoustics

ABSTRACT

The use of light steel framing as a method of house construction has increased significantly throughout Europe in recent years. The steel industry has supported an intensive technical development, and housing systems are now available, which are highly adaptable in form and use. For example, in the UK, the market share for steel has reached approximately 5% of current house and apartment building. This paper describes the general forms of construction that have been adopted, and the levels of performance that are achieved. Recent developments associated with the use of light steel modules and steel frames in medium-rise residential buildings are also presented.

1. Introduction

Light steel framed housing comprises walls and floors fabricated from galvanised C, Sigma or similar cold formed sections of 1.2 to 3.2 mm thickness. In the UK, approximately 5000 houses and apartments have so far been constructed and some success is being experienced in France, Netherlands, Sweden and Finland. In housing, the most common form of light steel construction involves prefabricated wall panels and elemental floors (where joists are installed as individual elements). This is known as platform construction. Construction of the second floor begins using the floor as a working platform.
2. Panelised systems

At Oxford Brookes University, a demonstration building was designed using the Corus ‘Surebuild’ system of light steel framing, and gave an opportunity for long term monitoring of its performance. (The completed building is shown in Fig 1).

The demonstration building includes habitable open roof spaces, a high level of thermal insulation, relocatable internal walls, light versatile foundations, and is designed for rapid erection. The building has approximately 275m$^2$ of usable floor area and consists of a two-storey house attached to a three-storey studio apartment building. The three-storey portion of the building includes three studio bedrooms and shared kitchen, plus a self-contained two person flat in the open roof space. The semi-detached house is self-contained and is typical of modern house construction in the UK. It has three bedrooms plus a habitable roof space that may be used as an office, playroom or fourth bedroom.

The framework comprises prefabricated storey-high wall panels constructed using 75mm deep steel studs, and floors constructed using 150mm deep joists. The platform construction uses the walls and floors to form a stable box. The roof members comprise ‘C’ shaped sections in an attic truss configuration on the two-story side of the building and purlins spanning between flank walls on the three-storey side of the building.

Before construction, the structural performance of the light steel framing was verified by an extensive series of full-scale tests under vertical and horizontal loads carried out by Corus in South Wales. The light steel framework was tested under horizontal load firstly without, and then with its brickwork cladding. A test on the light steel framework is illustrated in Fig 2.

The measured U-value of the wall was 0.216 W/m$^2$K, which compares well with the theoretically calculated value of 0.2 W/m$^2$K. The U-value compares very favourably current recommended best practice in the UK. The acoustic insulation of the walls exceeds the requirements of the current UK Building Regulations- see Table 1.

<table>
<thead>
<tr>
<th>Oxford Brookes University demonstration building (dB)</th>
<th>$D_{nTw}$</th>
<th>$C_{tr}$</th>
<th>$D_{nTw} + C_{tr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne sound insulation of wall ($D_{nTw}$)</td>
<td>65</td>
<td>-9</td>
<td>56</td>
</tr>
<tr>
<td>Airborne sound insulation of floor ($D_{nTw}$)</td>
<td>57</td>
<td>-8</td>
<td>49</td>
</tr>
<tr>
<td>Impact sound transmission of floor ($L_{nTw}$)</td>
<td></td>
<td></td>
<td>$D_{nTw} + C_{r}$</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td></td>
<td>54</td>
</tr>
</tbody>
</table>

Table 1: Summary of the acoustic performance of the demonstration building
3. Modular housing systems

The Murray Grove housing project in Hackney, London was designed by architects Cartwright Pickard for the Peabody Trust, a major housing association in the UK. The client wished to procure a building that was architecturally interesting, of a high and reliable quality, and which could be constructed quickly. A modular approach was therefore adopted and the design was developed together with manufacturers, Yorkon.

The building is 5 stories high and is located on a tight corner site. The majority of the accommodation was constructed using 3.2m wide modules. Two modules were used for one-bedroom flats and three modules for two bedroom flats. Other building elements including the cylindrical stair tower, external access balconies and monopitch roof, were all prefabricated. Stability to the access ways was provided by external bracing. The external façade to the street consists of terracotta tiles, whilst the façade to the courtyard behind the building incorporates steel balconies to all of the apartments.

Modular construction has also beginning to be used for refurbishment projects. A recent project for student accommodation in Plymouth carried out by a specialist key worker accommodation provider ‘Unite’, and has involved placing 28 modular bedrooms on the roof of a 4 storey former office building. The modules were fully fitted out and were fully serviced before delivery to site. They were constructed with open sides as in Fig 5. The extension was clad using a proprietary curtain walling system.
The modules comprised 75mm deep x 1.6 mm wall studs and 225mm deep lattice joists. Square hollow sections were introduced as corner posts on the front façade so that windows could extend over the module width. The open-sided modules were constructed so that adjacent modules could be placed together to minimise the internal wall thickness and meet tight internal planning requirements. Open-sided modules lead to flexible space use. Installation of the modules took only 3 days.

4. Adaptable and sustainable construction

A recent ECSC demonstration project has resulted in 5 housing and residential buildings that are designed for rapid construction and excellent performance characteristics. In the UK project, a ‘hybrid’ panel and modular building was constructed in which the toilet-bedrooms, kitchens and stairs were all constructed as modules. The load bearing walls and floors were constructed as 2D-elements. The completed prototype building is illustrated in Fig 6.

![Figure 6. ‘Hybrid’ modular and panel building](image)

The floor system consists of a plyweb beam that comprises C section flanges and two plywood webs. These 320 mm deep beams span 5.25 m between load-bearing walls and internal walls could be positioned to suit user’s requirements. These beams were subject to extreme testing which showed a load capacity in excess of 4 kN/m². They also possess excellent acoustic and thermal insulation properties, as established from on-site tests.

Similar demonstration projects have been completed in Finland, Sweden, Germany, France and Italy. In principle, this ‘hybrid’ technology could be used to create a new way of building for urban locations, as illustrated in Fig 8.

![Figure 7. Plyweb beam](image)

![Figure 8. Urban street-scape created by mixed use of panels and modules (courtesy HTA Architects, London)](image)
5. Medium-rise buildings

The market for steel in 4-8 storey residential buildings is also growing and has reached 20% of the apartment sector, which is itself close to 30% of current house building in the UK. Figure 9 shows a recent example of steel using Slimdek, which achieves the advantage of a flat floor of minimum depth which means that walls can be positioned without concern for beam positions. Often square hollow section (SHS) columns of not more than 200 mm are used, in order to fit within separating walls. Light steel infill walls and separating walls are used in all forms of construction, as they are lightweight and can be installed rapidly, and are re-locatable, leading to future adaptability.

![Slimdek construction in an apartment building (before concreting)](image)

Figure 9. Slimdek construction in an apartment building (before concreting)

The world’s largest modular building was constructed in Manchester in 2002 and consists of over 1000 modules, as shown in Fig 11. Stability is provided by braced steel cores located at the corner of the building. The modules have pre-attached cladding and can be relocated in the future.

![9-storey modular building in Manchester](image)

Figure 10: 9-storey modular building in Manchester

6. References

Steel Construction in Housing – Brochure of four demonstration buildings for the UK, France, Germany and Finland