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Design Analysis of Structures for Residential Light Steel Framing Systems

Amarildo V. Moreira, JR.
Department of Civil & Environmental Engineering
Howard University
Washington, DC, USA.

Amarildo V. Moreira, JR.
Coordination for the Improvement of Higher Education Personnel – CAPES
Brazil Science Mobility Program
Brasilia, DF, Brazil.

***Abstract* — The light steel framing technology has progressively increased because of the fast progress in the building industry. It has a lot of advantages from the technological point of view. The development of dry building systems based on steel members have spread in the US, Australia and Japan; and are now gaining market in European countries as well as in countries in development such as China and Brazil. These dry buildings address a new form of construction in which steel members are designed to act with "dry" materials, such as gypsum plasterboards. Although the gypsum plasterboards have a structural function, they are not normally used for taking active loads. The structure itself is made of steel frames. The systems often have load-bearing walls, and the floors may be of light weight steel profiles. They are designed for industrial production and can contribute to a more efficient building process.**

Keywords*— *Light steel framing; Residential Construction Systems; Shear walls; Gypsum plasterboards.

I. INTRODUCTION

Nowadays, one of the biggest dilemmas in Civil Engineering construction especially in development countries has been the amount of time spent for the buildings to be constructed. This situation of slow process may be due to the fact that most structures are built following in the traditional use of concrete, which takes a long time to be completely cured. The lack of understanding in different processes and technologies does not allow builders to improve their operation as far as time is concerned. However, the steel framing technique has been shown as a practical, efficient solution to many of the limitations that builders face using other materials.

The Light Steel Framing is a technique with a "skeleton frame" of vertical steel columns and horizontal I-beams, constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. It is an alternative to build quickly as well as have a cleaner construction environment and decrease wasted materials that impact directly in the final budget. According to the Builders Guide of Steel Frame Construction, from the Steel Frame Alliance, more than 40% commercial structures now are using steel framing and with nearly 500 homes in the US built with steel framing over the past decade. [5]

The use of steel framing continues to grow year by year and is a trend for the future.

II. ROLL FORMING PROCESS

The Light Steel Frames (LSF) are made by a process called roll cold-forming in which a long strip of sheet steel is passed through a series of rollers to form the bends and create the desired shape. The frames are manufactured at room temperatures, relatively considered low temperatures (cold working) and the strength is achieved by a combination of properties of the steel, such as thickness.

Fig. 1 and Fig. 2: Steel sheet in roll-forming process
Source: YouTube, "Roll forming".

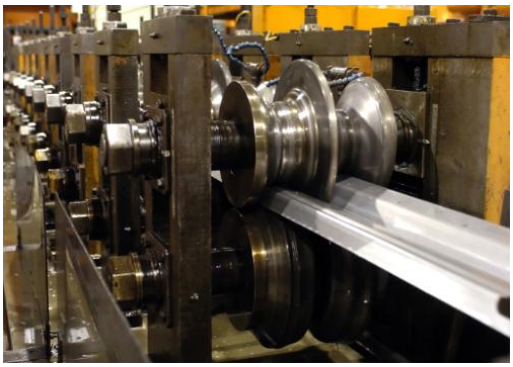


Fig. 3: Roll-forming process.

The steel used in the light steel framing systems is zinc galvanized because it needs to be protected from rusting, which can lead to damage during storage or even loss of strength during the construction phase.

In terms of thermal and acoustical approach, the elements of the frame are assembled in a way that the gaps in between can be filled with mineral wool as an insulation substance for heat and sound. Generally some minimum requirements

regarding the thermal transmittance of external building elements have to be met in LSF systems as well as requirements for sound insulation, according to the standards of each country (other products can also be utilized for insulation but mineral wool is most widely used for its benefits and efficiency in terms of fire protection).

III. EXTERNAL AND INTERNAL WALLS

Cold formed steel sections have been progressively used as primary structural members, such as load-bearing walls, or beams and columns. In the load-bearing walls, the connection between the members in the floor and wall allows direct load transfer. Generally, internal and external walls in light steel framing systems provide resistance to vertical loads transferred from the floors and roof, resistance to horizontal loads (and stability of the whole building), and resistance to out wind loads.

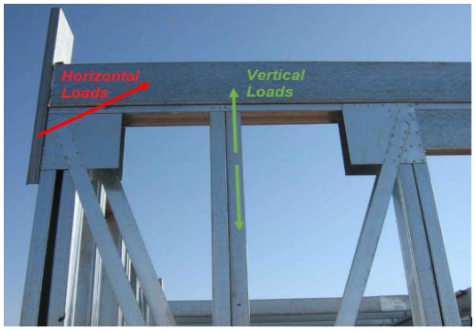


Fig. 4: Steel framed walls and its loads

These dry buildings address a new form of construction in which steel members are designed to act with "dry" materials, such gypsum plasterboards. Although the gypsum plasterboards have a structural function, they are not normally counted for taking active loads. They are designed for industrial production and can contribute to a more efficient building process. The most common element sections of Light Steel Frame structural systems are C and U profiles. Usually, they are of 75 to 200 mm depth with a flange width of 40 to 75 mm. However, there are a huge variety of other sections that can be produced of light steel. The cavity are normally filled with some material to improve specific performance.

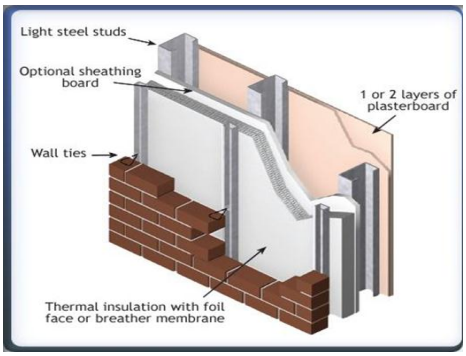


Fig. 5: Load-bearing wall components in LSF systems

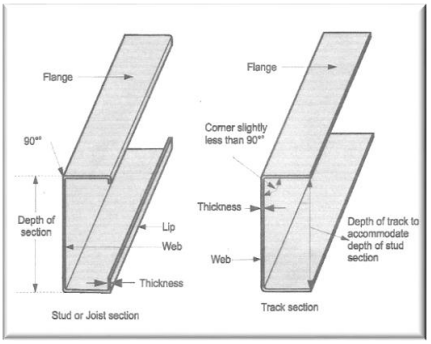


Fig. 6: C-profile section

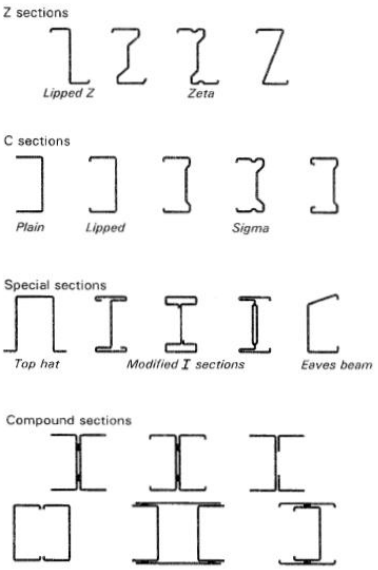


Fig. 7: Different forms of light steel sections.
Source: [3]

IV. STEEL FRAMING ASSEMBLY METHODS DESIGN

The method of construction is one of the most essential thing when it comes to Light Steel Framing design. Different methods can impact in different ways the construction, affecting the time of construction, the final cost and also the quality of the building. In terms of assembly methods, the two main classifications are: stick framing and panelization.

A. Stick-Built Construction (Stick Framing)

"Stick framing" is basically the same in wood and steel. This framing method has actually gone through a transformation incorporating many of the techniques used in panelized construction. It involves assembling the floors and walls using individual studs and joists on the construction site. The layout and assembly of steel framing is the same as for lumber, except components are screwed together rather than nailed. It requires extensive cutting of individual framing members, and requires a fairly high level of skill of framers who must know to assemble the elements within the house.

B. Panelization

Panelization is based on assembling elements of the building – such as walls, floors and roofs – in a controlled manufacturing environment, and it has been progressively used in residential construction today. It consists in pre-fabrication of the construction components repeating the panel dimensions and types – that can be produced in industry or on site construction – and results in a process four times faster. "A jig is developed for each type of panel. Steel studs and joists are ordered cut-to-length for most panel work, placed into the jig and fastened either by screws or welding. The exterior sheathing, or in some cases, the complete exterior finish, is applied to the panel prior to erection". [1]

Fig. 8 and Fig. 9: Pre-fabrication of panels and components
Source: Google

This method is well accepted and used for providing an efficient building process even in bad weather conditions. Steel framing suits well for panelization because it is manufactured with precision to meet exact sizes, and its light weight allows for easier handling of assembled components.

V. SUSTAINABLE APPROACH AND ENVIRONMENTAL BENEFITS

As the worldwide production and consumption increases, the use of resources like energy increases as well. There is a need to develop new ways of construction that cause less impact to the natural environment and reduce the use of basic materials.

"In the ecological architecture the most important issue is the enforcement of the viewpoints of environment protection and public health protection. During the building, the environment protection is reachable by reducing significantly the energy consumption by: 1) application of building materials with low embodied energy; 2) employment of recyclable building materials; 3) usage of a building technology with low energy need, etc." [2]

Steel components generate minimal waste and all light steel construction materials are completely recyclable, therefore a healthy environment is guaranteed. In addition, applying possible natural materials and technologies are absolutely harmless to people. For this reason, the light steel framing system has a general advance for providing health protection.

VI. STABILIZATION SYSTEM WITH SHEAR WALLS

In structural engineering, a shear wall is a wall composed of braced panels to counter the effects of lateral load acting on structure. Wind and seismic loads are the most common loads braced wall lines are designed to counteract. In other words, shear wall is a wall specifically designed to support horizontal loads and provides lateral resistance in the building.

In Light Steel Framing systems, horizontal loads are resisted by diagonal bracing. By resisting these horizontal loads, the stabilization of the buildings is more likely to happen. The shear walls are made of steel profiles or gypsum plasterboards, although the gypsum plasterboards are not accepted as a structural component and are not used for stabilization in the United States.

Differently, a design method for single-layer gypsum plasterboards was developed by Kallsner and Åkerlund and officially recognized in the Swedish Building Regulations [6] in 1975. It allowed a shear force of 0,1 kN for a 1.7 mm nail in a 13 mm gypsum board. Since the minimum space of the nails was 100 mm limiting the shear flow to 1 kN/m, this is small load was considered an important decision. Although some people may seem uncomfortable with gypsum plasterboards used for structural purposes, recent researches have been shown that they can be used with shear walls to stabilize building systems. [4]

VII. THERMAL AND ACOUSTIC APPROACH

In terms of thermal and acoustical approach, the elements of the frame are assembled in a way that the gaps in between can be filled with mineral wool as an insulation substance for heat and sound (other components can also be utilized for insulation but mineral wool is most widely used for its benefits and efficiency in terms of fire protection).

Minimum requirements regarding the thermal transmittance of external building elements have to be met in LSF systems as well as requirements for sound insulation, according to the standards of each country.

A. Separating Walls

The light steel framing system relies on the degree of structural isolation that is achieved between the several layers of the construction to achieve good acoustic performance. In separating walls, double skin construction is used with minimal structural connection between them. A range of wall construction with their respective acoustic insulation and fire resistance is represented in Table 1. [3]

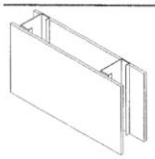
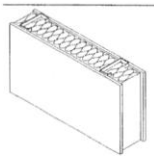
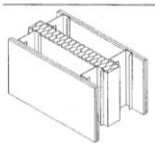
	Materials Specification	Acoustic Separation D_nT_w	Fire Resistance
	• 12.5 mm plasterboard • Light steel studs • 12.5 mm plasterboard	35 dB	30 min
	• 12.5 mm plasterboard • Light steel studs with mineral wool between • 12.5 mm plasterboard	45 dB	30 min
	• 2 layers of 12.5 mm plasterboard • Light steel studs with mineral wool between • 2 layers of12.5 mm plasterboard	50 dB	60 min
	• 2 layers of 12.5 mm plasterboard • Resilient bars • Light steel studs with mineral wool between • Resilient bars • 2 layers of12.5 mm plasterboard	58-60 dB	60 min
	• 2 layers of 12.5 mm plasterboard • Light steel studs • Clear structural cavity between studs filled with mineral wool • Light steel joists • 2 layers of12.5 mm plasterboard	60-65 dB	60 min

Table 1: Sound insulation and fire resistance light steel wall constructions.

[3]

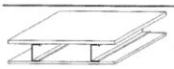
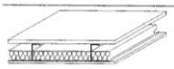
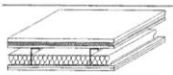
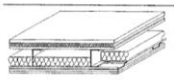
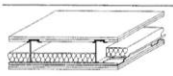
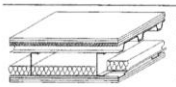
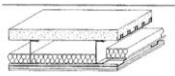
	Materials Specification	Acoustic Separation D_nT_w	Fire Resistance
	• 18 mm chipboard • Light steel joists • 12.5 mm plasterboard	D_{nTw} = 33 L_{nTw} = 83	30 min
	• 18 mm chipboard • Light steel joists • 100 mm mineral wool between joists • 12.5 mm plasterboard	D_{nTw} = 42 L_{nTw} = 76	30 min
	• 19 mm cement particle board • >10 mm resilient layer • Chipboard, OSB or plywood • Light steel joists • 100 mm mineral wool • 2 layers of plasterboard (total thickness 30 mm)	D_{nTw} = 52 L_{nTw} = 61	60 min
	• 18 mm T&G chipboard • 19 mm plasterboard • 25-30 mm mineral wool or glass wool • Chipboard, OSB or plywood base • Light steel joists • 100 mm mineral wool between joists • Resilient bars • 2 layers of plasterboard (total thickness 30 mm)	D_{nTw} = 57-60 L_{nTw} = 54-57	60 min
	• 18 mm T&G chipboard • Proprietary top hat isolating section • Plasterboard between the top hat section • Light steel joists • Mineral wool between joists • Resilient bars • 2 layers of plasterboard (total thickness 30 mm)	D_{nTw} = 55 L_{nTw} = 59	60 min
	• 18 mm T&G chipboard • 19 mm plasterboard • 25-30 mm mineral wool or glass wool • 30 mm profiled steel decking • Light steel joists • Mineral wool between joists • 2 layers of plasterboard (total thickness 30 mm)	D_{nTw} = 55 L_{nTw} = 59	60 min
	• Composite steel and concrete slab • Light steel joists • Mineral wool between joists • Resilient bars • 2 layers of plasterboard (total thickness 30 mm)	D_{nTw} = 55-59 L_{nTw} = 53-59	60 min

Table 2: Sound insulation and fire resistance of light steel floors

B. Separating Floors

For separating floors, airborne and impact sound transmission must be taken into consideration. The same process used for walls should be also applied for lightweight floors, achieving high levels of acoustic insulation. It is recommended to separate the top surface of a resilient layer between the top floor finish and the structure below, and by resilient bars used to isolate the dry lining ceiling finish. A series of typical floor constructions is presented in Table 2.

C. Thermal Bridges

Thermal bridges of various degrees can be formed by load-bearing members in an insulated structure. It can lead to additional heat losses and lower surface temperatures on the room side, which can be disadvantageous for the system. Therefore, it is recommended that thermal bridges must be reduced in the light steel framing system. The effect of thermal bridges can be reduced by three methods: 1) using double frame systems; 2) using exterior insulation systems; 3) using perforated the steel profiles, thermo-profiles.

Also, it is relevant to mention that in light steel framed buildings, the connection details of prefabricated external wall elements, the connection between walls and floors (ground plate/basement and roof), as well as the details of windows connection and steel sections penetrating though the heat insulated building are all important and have to be closely monitored. [3]

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REFERENCES

[1] S. Shi, J. Yu, "Development of Chinese Light Steel Construction Residential Building", Journal of Sustainable Development, November 2009. Vol. 2, No. 3 : pp. 134-138.

[2] A. Dudás, "Light Steel Structures in Residential House Construction". Periodica Polytechnica. Ser. CIV. ENG. VOL. 47, NO. 1, PP. 133–136 (2003).

[3] J. Strömberg, M. Lawson, R. Kergen, A. Moutafidou, T. Mononen, B. Johansson, J. Nieminen, "Development of Dry Composite Construction Systems Based on Steel in Residential Application" (2002).

[4] M. Veljkovic, B. Johansson, "Light Steel Framing for Residential Buildings". University of Technology. Thin-Walled Structures 44 (2006) pp: 1272 – 1279.

[5] A Builder's Guide to Steel Frame Construction. Steel Framing Alliance (2007).

[6] SBN 1975. Swedish Building Regulations. Statens Planverk, 1975.