TÉCNICO LISBOA

The use of cold-formed steel profiles in the refurbishment of buildings

Extended Abstract

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Dissertation to obtain the Master's degree in

Construction and Rehabilitation

Jury

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October 2012

Abstract

This research has as its main goal the study of the use of cold-formed steel members for the refurbishment and extension of buildings. A state-of-art is presented, concerning the main use of these solutions on low density residential and retail typologies, usually known as *light steel framing* construction (LSF). The products used on these solutions and constructive methods are characterized and technical considerations are presented on performance requirements for the listed topics: waterproofing, thermal insulation, air and vapour tightness, acoustic behaviour and fire proofing. It is presented a comparison of solutions for floors up to 4 meters length and non-structural internal walls, using as variables the cost, speed of execution and net-weight, confronting this constructive system with timber structures and concrete prefabricated products and ceramic masonry. This research also includes a case-study survey on the use of these solutions on the rehabilitation of buildings, resulting in a representation of the Portuguese practice.

Keywords

cold-formed; steel profiles; construction; rehabilitation; refurbishment; cost comparison

1 Introduction

The present dissertation has the purpose of achieve a greater understanding on the science of construction using structural cold-formed members for the refurbishment and expansion of buildings, while the main use for these products is centered for low density residential and retail typologies, usually known as “light steel framing” (LSF).

These constructive systems have characteristics that promote their use for the intervention in existing buildings, either for the replacement of part or all the interior core, justified by functional and physical obsolescence; or for vertical upgrading, with the replacement of roofs or overlapping new floors, in case of the existing structure being able to support the overweight or is reinforced for this purpose.

The ease and speed on the assembling of these structures constitutes a robust potential in its application for the concept of systematic urban rehabilitation, always regarding technical limitations and historical or heritage factors that could exclude its use.

The advantages of this building system are addressed but also its characteristic limitations, as well is compared with other refurbishment oriented solutions, including the use of timber structures and precast concrete and ceramic masonry products.

The research also includes a survey of case studies in buildings that use these structures in renovation works, giving a general picture of its use on the Portuguese territory.

2 General characterization

This chapter is composed by the description of the materials and products used in the construction of buildings with cold-formed steel structure. Besides characterizing the products, also describes the fastening methods, structural sheathing and interior and exterior cladding. The potential of light steel framing structures as a solution highly sustainable is highlighted, due to reduced energy consumption during the construction, as well as low waste generation, and due to

the fact of being relatively easy to achieve low energy cost during the operational phase of the building.

2.1 Historic evolution

The introduction of cold-formed products occurs initially on the building sector as external cladding or under-cladding, starting to being published, from the beginning of the 20th century, prototypical housing models using minimal self-supporting profiled sheets. The mainly experimental period continued until the Second World War when, in 1946, is published in the U.S. the first *Specification of Cold-formed Products* by the American Iron and Steel Institute. Thereafter the use of these building systems becomes ruled in this country, leading to the growing of a dedicated industry and development of related products (fastening systems, insulation products, sheathing). This document suffers several updates before other countries develop and publish equivalent counterparts (1974, the publication of the AS-1538 Australian Standard).

2.2 Definition and material

The cold-formed steel products result from the bending of the steel sheet in room temperature, resulting profiles with higher resistance of the original flat sheet. The cross-section of a cold-formed member or profiled sheet comprises straight and curved elements. In additional to the folds that characterize each profile's design (ex.: U, C, Z), additional bends or grooves called *stiffeners* can be incorporated in the edges or middle of the flange, with the function of improving the mechanical properties.

The structural members used commonly in the construction of low density residential and retail buildings are between 1,0 and 3,0 mm thick.

2.3 Products

The cold-fomed products are distinguished into two groups, depending on use and length of the cross-section: profiles and profiled sheets.

2.3.1 Structural profiles

These can be open, closed built-in sections. The most commonly used sections are U, C, Z, Σ and Ω and often its designation is related to the function or shape.

2.3.2 Profiled sheets

Another group includes the corrugated panels and profiled sheets that, with different configurations, widths and thickness, are used in sheathing, decking and composite floor applications.

2.4 Forming methods

Roll forming is the method which enables the large scale production of cold-formed structural and non-structural steel profiles, allowing its competitiveness against other constructive solutions. The metal strip (sheet metal) is introduced through a succession of pairs of rollers that will deform it progressively, through several stages, before achieving the final shape. The inclusion of holes and slots can be performed prior or following the rolling process. The sections can be trimmed to the desired lenght before or after this process, being the dimensions only limited by transport and storage

restrictions.

2.5 Corrosion protection

The main form of protecting the steel used for structural cold-formed profiles is hot-dip galvanizing. This process consists in immersing the steel elements into a tank containing molted zinc at 450 ºC which after cooling down will form a series of layers composed by a steel and zinc alloy. This protection will, firstly encapsulate the steel, preventing it from contacting the water and oxygen, and secondly consist a sacrificial layer, wearing in priority when in contact with steel. This effect dramatically delays the process of steel corrosion and will maintain a high level of protection of the trimmed edges and scratched surfaces.

3 Constructive solutions

Chapter 3 refers to the description of the construction systems and structural methods used with these products. While the purpose of this dissertation is to identify the techniques and describe the constructive solutions for the intervention in existing buildings, the specific literature on this topic has proved to be relatively limited and, even when found, somehow generic. For this reason the presented state of art relates mainly to new construction, introducing, where appropriated, considerations on the retrofit and extension of existing buildings.

The chapter introduces a description of the construction stages and how are designed and executed the various components of a building using the *stick construction* method. This one is the most commonly in Portugal and is also the one that better adapts to the application of this building system in existing buildings with irregular plants.

This chapter also includes a section dedicated to the technical considerations to have in account in the design and specification of the building components, concerning performance requirements in topics as waterproofing, thermal insulation, air and vapour tightness, acoustic behaviour and fire proofing.

3.1 Building retrofit and extension solutions

In this context the main applications of these products are:

- internal partitioning;
- over-cladding;
- over-roofing and roof replacement;
- vertical extension;
- attachment or insertion of volumetric modules, such as toilet units, elevator shafts or stairs;
- vertical partitioning (*mezzanines*).

These solutions don't apply, however, for the structural retention of brickwork or masonry façades, execution of foundations or retaining walls, where should be used seismic resistant elements, usually using reinforced concrete or hot-rolled steel technologies.

4 Comparison with alternative retrofit solutions

In order to contextualize the integration of these solutions in the general construction overview it is necessary to consider

specific factors of comparison, such as cost and execution runtime. So, to consider the competitiveness of cold-formed steel structures it is presented a data survey that characterize different building systems with application in the refurbishment and extension of buildings:

- cold-formed steel profiles;
- timber structure;
- concrete precast products and ceramic masonry.

In order to objectify the comparison were selected two building components:

- floor slab with up to 4 m length;
- non-structural internal wall.

The variables compared are:

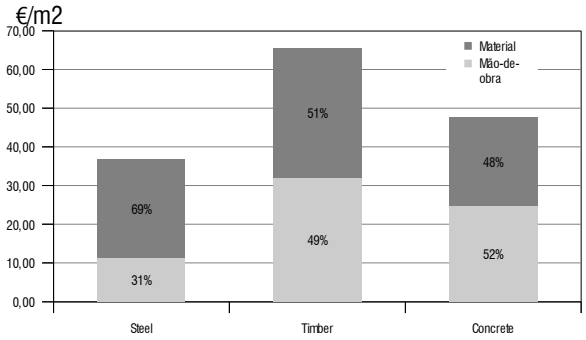
- material and labor cost;
- execution time;
- building components net-weight.

The data concerning this variables was gathered contacting engineering consultants, suppliers and quantity and cost surveying databases.

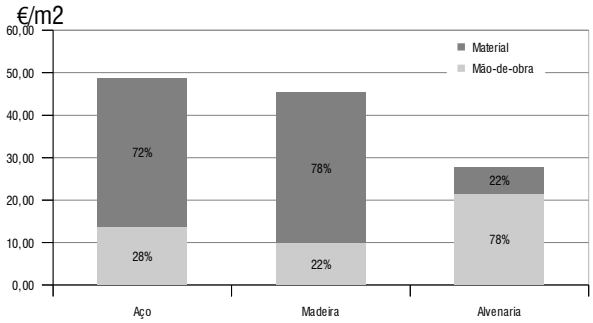
4.1 Data analysis

When the values on cost, net weigh and execution time are compared, the advantage of the floor slab solution that uses cold-fomed members is clear for all items. Another evident point relates to the proportion between material cost *versus* labor cost, in which this solution, although with higher material cost comparing with the concrete alternative, has a much lower consumption for the labor. On the net-weight topic the precast concrete joist floor has a weight 13 times higher compared with the cold-fomed profiles floor. The floor solution with timber structure is the one that presents the higher cost and slower building, although on the net-weight issue is only 20 kg/m^2 heavier than the metallic one.

The comparison for the interior walls shows dissimilar results. Regarding to cost, the one that is based in brickwork gets the smaller value, with the cavity solutions being one third more expensive. The timber solution is the one that spends less time to be built, followed by the metallic one and finally the masonry, which is twice slower.



1: Floor slab cost comparison



2: Non-structural internal wall cost comparison

5 Case studies

This paper describes interventions in existing buildings using constructive solution based on the use of cold-formed steel profiles structures. The insertion of these case studies in this work pretends to demonstrate the ability and adaptation that these solutions offer for refurbishment uses.

3: R. Cecílio de Souza, Lisbon

4: Rua Garrett e Rua Anchieta, Lisbon

5: Calçada do Combro, Lisbon

6: Frazão, Paços de Ferreira

7: Rua Gago Coutinho / Rua Francisco Luís Lopes, Sines

8: Beja Town Center

5.1 Residential building - R. Cecílio de Souza, Lisbon

The intervention carried out in Rua Cecílio de Souza covers a building composed by masonry walls and timber structure in floors and roof. The purposes of the intervention were: replace the roof, which was cause of leaking to the underneath floors; reinforce the 3rd floor slab, with the objective of maintain the heritage listed ceiling of the main salon located in the

2nd floor; replace the 4th floor (roof level) slab and introduce partition walls with a new layout.

The structural intervention inserts a hot-rolled steel *podium* structure for the reinforcement of the 3rd floor original slab and reinforced concrete beams in the upper edge of the front, back and gable wallls. The LSF structure is used for the roof floor slab, roof and dormers, as well for the central corridor structural walls, these being fixed to the concrete members and hot-rolled steel structure.

5.2 Residential and retail building - Rua Garrett / Rua Anchieta, Lisbon

The intervention was performed in two phases and consisted in the replacement of the roof and roof level floor slab, access stair (excluding structural core), functional redesign of housing layout and reinforcement of timber floors.

5.3 Residential and public services building - Calçada do Combro, Lisbon

The cold-formed steel profiles were used in the reinforcement of the 3rd floor slab, execution of a new slab on the 4th floor, roofs, dormer windows and partition walls.

5.4 Detached house - Frazão, Paços de Ferreira

The intervention is made on a ruin of an ancient rural building composed by granite masonry walls. The retroftting construction uses cold-fomed members for the roof structure and partition and supporting walls in the upper floor.

5.5 Residential building – Rua Gago Coutinho / Rua Francisco Luís Lopes, Sines

This work has as base of intervention a building with a previous warehouse function, specifically a cellar. The walls are made of stone, brick and lime masonry. The work was performed in two phases. The first consisted in the execution of reinforced concrete capping beams on the top edge of the walls, working as a diaphragm connection between these and also providing a supporting for the cold-fomed structure of the roof. A second step involved the demolition of the partitioning inner walls, rehabilitation of selected masonry surfaces by applying fiberglass (alkalis-resistant) net and lime based render, grout injections for filling wall core hollows, horizontal and vertical partitioning and finishing coatings.

5.6 Residential and retail building - Beja town center

The intervention is performed in a two-storey building consisting of exterior and interior walls of ordinary thick masonry, floor and rooftop structure with wooden floor and cover with wood structure embedded in the walls and ceramic tile flooring. The retrofitting works introduce a new roof, 1st floor slab and partition walls, as well a new access staircase.

6 Conclusions

The outcome obtained through the consulted bibliography, interviewed professionals and visited construction sites permits to conclude that the employment of cold-formed steel members for refurbishment works presents several advantages: lightness, adaptability, fast erection and few requirements of area for storage and working on site.

However the use of this construction systems on existing buildings with heavy elements, like ordinary masonry walls, doesn't replace the need of reinforcement using dedicated structural technologies, as concrete or hot-rolled steel members.

“Stick construction” reveals itself as the construction method that better adapts to the refurbishment and extension of buildings, especially in the cases where the original architecture is characterized by an irregular plan layout or is impossible to survey it accurately prior the demolition or removing of the existing structure.

On the comparison with other constructive solutions the use of cold-formed members for the execution of slabs presents

very competitive values for all the variables. However either this solution and the one based in timber structure aren't designed as final, concerning to acoustic and fire-proofing requirements, in opposition to the alternative based in concrete products.

When comparing the partition wall solutions one of the factors that explains the reason that the steel profiled wall seem less beneficial than the timber wall appears to be the unsuitability of the product to the function. If we consider a structure using non-structural steel profiles the cost, execution time and weight can be reduced, resulting in a more competitive solution.

Due to the fact of the history of application of these products is still limited and hasn't been possible to obtain data directly from contractors, the comparison here presented has some degree of relativity, being needed further studies with the same variables but comparing solutions with equivalent performance profiles and using “real” market data.