Cold-formed Steel Framing of a Dairy Products Warehouse in Brest, Belarus

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Abstract. The main advantages and disadvantages of cold-formed steel framed structures are discussed, and the basic principles for their analysis and design are considered. Some specific structural features of the thin-walled cold-formed steel framing of a dairy warehouse designed by Proekt-nauka LLC (Brest, RB), are described, and several recommendations so as to improve its structural design are given.

Introduction

Nowadays, there is an increased demand for light-gauge cold-formed steel (CFS) buildings and structures which are dry-assembled from prefabricated thin-walled galvanized CFS members by bolted connections. Such members are produced from thin-walled CFS sections of various cross-sectional configurations which are, in turn, fabricated from cold rolled sheet steels using specialized cold roll forming machines. Due to an increased anti-corrosion resistance (provided by the hot-dip galvanized types of steel being used), as well as strength, cost-effectiveness and aesthetics of CFS buildings and structures, the CFS construction is rightfully gaining popularity on a global scale as an alternative to traditional methods of construction [1, 2].

The main advantages of CFS framed buildings and structures are known to be:

• Low metal consumption resulting, in particular, from a rational structural design and optimal cross-sectional dimensions of thin-walled CFS members, the use of high-strength steels and aluminum alloys. The manufacturing and erection technologies now in use allow the amount of metal used in CFS structures to be reduced almost twofold in comparison with traditional design solutions, while decreasing the total weight of the building almost threefold.

• Ease of assembly. A prefabricated CFS building or structure is transported to the construction site unassembled, in bundles, which allows the construction process to be carried out on a turn-key basis. The delivered prefab CFS structural components can then be dry-assembled by bolting them together, with no welding operations being required.

• The assembly speed in case of CFS buildings and structures is almost twice as high as it is when using traditional construction technologies and building materials.

• Durability and strength. The CFS structures have proved to successfully retain their serviceability for a long period of time.

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• High degree of fire-resistance.

• The small self-weight which is characteristic of CFS members tends to significantly reduce the amount of load coming onto the foundation.

• Fast dismantling. CFS structures can be easily disassembled and transported elsewhere by road or rail.

• Possibility of using CFS structures in regions with harsh climatic conditions, as the CFS framing can be thermally protected with various thermal insulation materials.

• Quality. The CFS sections are typically manufactured in specialized rolling mills where they are necessarily checked for compliance with building codes.

• Feasibility for challenging architectural projects to be implemented at lower financial costs.

Even though CFS sections have many advantages, there are also some disadvantages in using them as a structural building material. Some of these disadvantages, that are in fact the adverse side effects of their benefits, are:

• Susceptibility to torsional deformation of CFS elements due to low torsional rigidity resulting from their thin walls.

• Large width-to-thickness ratio which the plate elements constituting the CFS sections typically have. As a result, the CFS sections turn out to inherently suffer from local, distortional, and global buckling modes.

• A high-quality analysis and design of CFS framed structures requires a rather deep insight into their structural behaviour, resulting in a complex optimization process, particularly in the fields of structural stability and joints [3].

Analysis and design of CFS framed structures

In the Republic of Belarus, the design and construction of buildings and structures assembled from thin-walled CFS members and sheeting with a thickness of $t < 3$ mm is specified by TKP EN 1993-1-1 [4] and TKP EN 1993-1-3 [5]. The most typical cross-sectional shapes of thin-walled CFS members are shown in Figure 1.

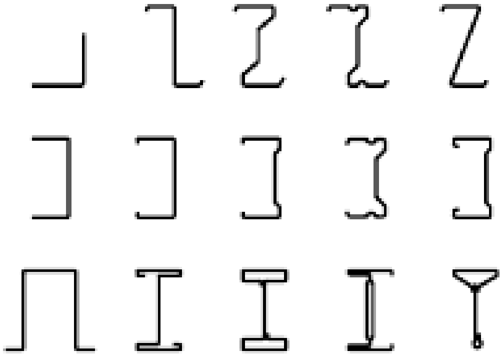

Fig. 1. Typical cross-sectional shapes of single open CFS sections

For the design of structures made of CFS members and sheeting, TKP EN 1993-1-3 establishes the following three structural classes associated with failure consequences:

- Structural class I: Structures in which CFS members and sheeting are designed to contribute to the strength and stability of the whole structure;

- Structural class II: Structures in which CFS members and sheeting are designed to ensure the strength and stability of individual structural elements;

- Structural class III: Structures in which CFS sheeting is used only to transfer loads to the load-bearing frame.

When designing CFS buildings and structures, one should take into account such phenomena as warping of flanges, local and distortional buckling [5, 6].

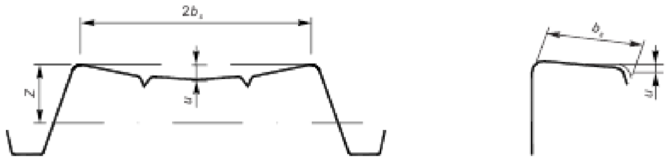

Fig. 2. Flange warping of open CFS sections

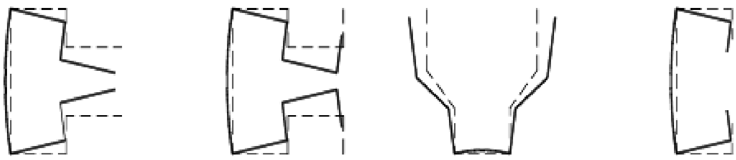

Fig. 3. Examples of distortional buckling modes

Storage chamber for finished dairy products (Brest, RB)

The working drawings of the CFS framed structure "A warehouse for dairy products, located in Brest, at 118/1 Ya. Kupala str." were completed, as mentioned earlier, by Proekt-nauka LLC (Brest, RB). According to its structural scheme, the warehouse is an attached one-story building, designed as a metal braced framework, with external curtain walls being made of sandwich panels. The design warehouse dimensions are 19.36m x 60.5m, its height being 27.05m.

In the transverse direction, the load-bearing framework of the high-rise chamber is formed by build-up Ω-shaped CFS columns, spaced apart at 4.5m, and built-up girders to support a mono-pitched roof. The exterior built-up columns are made up of three studs, while the interior ones are composed of four studs.

Individual Ω-shaped CFS studs are tied together to form a column by means of diagonal and transverse lacing bars (braces). The connection of lacing bars to the studs is by a hinged joint.

The built-up girders are load-bearing components of the roofing structure, and consist of two, top and bottom, chords of Ω-shaped CFS sections which are interconnected by diagonal braces made of closed CFS sections of tubular cross-section. The girders are of weld-fabrication, and are semi-rigidly attached to the framework's columns at its bottom chord.

A preliminary design of the building framed structure, along with the determination of the cross-sectional parameters for all structural elements, had been carried out by Riko LLC (Slovenia).

To assess the overall designed stability and strength of the building framework, while taking into account the country-specific TNPA in force in the Republic of Belarus, the building structure was analyzed as a spatial system, making use of the Autodesk Robot Structural Analysis Professional software package at the Proekt-nauka LLC premises. Static calculations, along with the compilation of the design combinations of forces, were performed in compliance with the requirements of the existing building codes. The verifying calculations of the main CFS elements of the building framework (Figure 4) were performed in line with the current TNPA provisions [4, 5, 7, 8], making use of the above mentioned software package.

The strength and stability of the building framework in the transverse direction is ensured by the bearing capacity of the columns, as single rods of built-up cross-section, the external row of which is rigidly embedded at one end into a monolithic foundation slab, while being semi-rigidly connected to the bottom chord of built-up girders.

The rigidity of the framework's longitudinal framing is provided by installation of vertical braces made of rectangular CFS sections (GOST 30245-2003).

The structural rigidity of the one-story building as a whole is ensured by installation of horizontal flexible braces attached to the heads of framework studs along the cooling chamber perimeter (Figure 5).

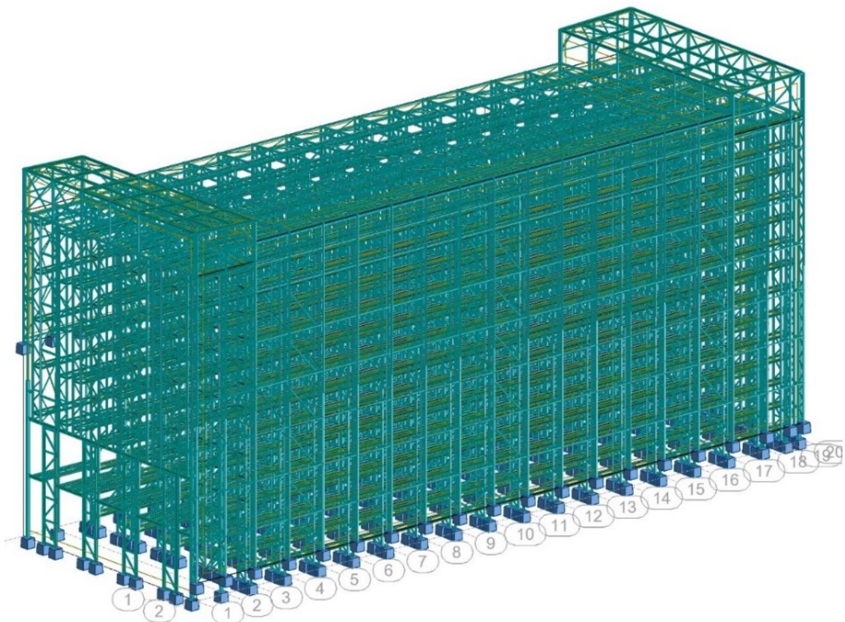

Fig. 4. 3-D view of the FE model

Fig. 5. The warehouse for dairy products under construction

Conclusions

Based on the results obtained through verifying calculations, the following conclusions were made [9, 10]:

- The studs' structural design does not meet the requirements specified in Clause 6.3.1.4 of TKP EN 1993-1-1 in terms of bending-torsional stability. It is recommended to reinforce all the studs of built-up columns with 70x50x2 mm steel tubular inserts starting from -1.350 and going up to + 1.350 levels.

- The girders design does not comply with the requirements of TKP EN 1993-1-1 Clause 6.3.2.4, namely: the bending-torsional stability of "pallet girders" with discrete lateral bracing of compressed flanges is not ensured. It is necessary to change the design lateral bracing scheme by providing two transverse braces (Σ 160x60x2.5 mm) with a distance of 600 mm between them.

- The roofing structure-related horizontal braces, as well as the vertical ones related to the studs of the air-coolers storage room, do not meet the requirements of TNPA. They need to be respectfully replaced with 16 and 20 mm prestressed steel round bars (GOST 2590).

- To ensure the structural rigidity of the roofing structure, it is required to increase the number of vertical braces (□ 60x3 mm) as per GOST 30245.

- Horizontal purlins in between axes 1A-2A should be placed in height with a step equal to the step of "pallet girders" (1.77m), while open thin-walled ∑-shaped CFA sections should be replaced with closed welded rectangular ones measuring 160x40x3 mm as per GOST 30245 [9, 10].

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