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ScienceDirect

Procedia Engineering 190 (2017) 186 – 192

Procedia Engineering

www.elsevier.com/locate/procedia

Structural and Physical Aspects of Construction Engineering

Numerical Modelling of Thin-walled Purlins Connection to the Supporting Structure

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Abstract

The advantage of thin-walled cold-formed steel profiles used as a carrying member in building structures is their low weight, which results to both material savings and simple assembly. However, the design disadvantages because of their large slenderness, which influence the local and global stability, occur. This phenomenon can have a significant influence to the total loadbearing capacity in comparison with the hot-rolled cross-sections. One of the critical sections can be assign in the support, because of the large influence of local forces action. Therefore this article deals with numerical models of thin-walled purlins overlap connection to the supporting structure. Numerical models are done especially for tall and slender purlins connected both – directly through the bottom flange or through the web using standard clip connection. The numerical models are understood as basis for future experimental tests of similar load connections.

Peer-review under responsibility of the organizing committee of SPACE 2016

Keywords: Thin-walled purlins; Connection; Steel; Numerical modelling; Overlap; Cripling

1. Introduction

The use of steel is popular as a solution for construction of industrial buildings and it is designed according to chosen EC [1]. It is caused by very good mechanical properties of steel [2, 3]. Steel allows to use many modern means of processing and treatment technology. Thin-walled profiles belong there [4, 5] which lead to reduction of weight and lower price. The disadvantage of thin-walled profiles are complicated methodology of design and check [6, 7 and 8]. Another disadvantages are mainly: loose of stability of an element, buckling or complicated design of structural connections and details [9]. Therefore, more advanced methods for design and analysis of civil structures are needed.

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Peer-review under responsibility of the organizing committee of SPACE 2016
doi:10.1016/j.proeng.2017.05.325

Typically, finite element method [10, 11] and non-linear analysis [12, 13 and 14] are used for numerical modelling of real behavior of steel constructions. In some cases, basic design processes of details for automatic design of common steel frame corner can be found [15]. A few types of thin walled profiles and their connections are used. Typical shapes of profiles are: Z and C [16, 17 and 18]. Connections are for example: without additional stiffeners, with stiffeners created by double overlap, and connections with additional clip [7]. With respect to amount of types of constructions and types of processing, all designs of these connection are not taken into account in available normative rules. That is a main motivation for this research. Verification of these connections or elements from thin walled profiles is implemented by simplified rules provided to producers of these constructions. Normative rules are usually issued using internal experiments. Their usage is often limited for typical cases. Laboratory experiments for chosen cases and calculation models are available [19, 20 and 21]. Detailed description of beam model is for example [22, 23]. With respect to the nature of the task, only narrow region of this problematic is solved. Use of connection elements is an important aspect of these constructions [24].

Roof purlins are typical application of thin walled profiles. With respect to increasing requirements for span of hall constructions, mainly higher profiles are used, which are not commonly used. This covers also a problem of connection of roof purlins to main bearing construction and assembly joints. Local concentrations of stress are formed in connection regions. These have a significant impact on load bearing capacity of thin walled profiles. These concentrations can be avoided using stiffening of beams in regions of local loading. There are many types of stiffening. Doubling of the section in places above support is the mostly used stiffening. Also, in the place of connection, many different stiffening clips for different solutions are used. For high beams such as Z300 and Z350, overlap with additional stiffening clip from steel seems to be the best solution. Effect of this clip for whole capacity of bending moment above support is subject of this research.

2. Design and analysis of thin-walled purlins

Calculation model of a beam is needed to be chosen precisely as well as boundary conditions which respect connection to other construction. Assumptions of beam theory are not adequate for beams from thin walled profiles. There may typically lead to the loss of stability and buckling. Load bearing capacity of the section is exhausted when yield strength is reached. Typically, load bearing capacity of thin wall section is calculated with reduced sectional characteristics. Therefore, these characteristics are marked as effective (i.e. A_{eff}, I_{eff}) Effective sectional characteristics are used in a beam calculation model to calculate internal forces. The use of plane and spatial calculation models is an advanced design and analysis of steel elements from thin walled profiles. Non-linearity are needed to be taken into account in calculation. Connection to another constructions is also a delicate issue of thin walled profiles. Local buckling in connection regions, shear stress, contact pressure, loose of stiffness of structural detail can occur. Procedure of design of construction details is realized for typical issues by analytical models and table values. These are taken from experimental measuring of specific types of details and them testing variants.

While solving problematic of optimization of design and analysis of high thin walled profiles and their connections, the research aims on: creation of design method, usage of advanced calculation models, check of effect of chosen parameters (thickness of metal sheet, width of purlin, height of profile) to total load bearing capacity and spread the database of optimized details by other types. Deduction of analytical relations for design of connection details is assumed for comfortable design in practice.

Article presents parametrical study for chosen type of connection of thin-wall profile. The study is based on usage of advanced numerical models, which include spatial calculation models and take into account physical, geometrical a structural nonlinearities. Software ANSYS was used for calculations [25].

3. Numerical model

The arrangement of a pair of Z beams that is planned to be experimentally tested is chosen for the parametric study. The Z-profile beams have the height of 300 mm and a thickness of 1.96 mm. Thin-walled beams are duplicated across the length and reinforced by a clip. Doubling is done in reason the weakest point of the beam area was support region under the load element, instead transition overlap for a continuous profile. Scheme assembly and connections shown in Fig. 1.