Numerical and experimental analysis of perforated rack members under compression

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ABSTRACT

This paper presents a numerical and experimental study of uprights with rack-type perforated section in cold-formed profiles, subjected to axial compression. 18 tests were performed on uprights with fixed-ends under uniform compression load to obtain the ultimate load applied, along with the measurement of the displacements. A numerical model with material and geometric nonlinearities was calibrated with the experimental tests. Next, a parametric analysis with 64 different numerical models was performed, determining the ultimate loads of the models. These results, when compared to the DSM predictions, showed that the equations of DSM are unreliable to predict the strength of this type of perforated uprights. Therefore, based on the model results, modifications were proposed to the parameters of the DSM distortional mode curve, so that it can predict the strength of the models studied.

1. Introduction

Cold-formed profiles are widely used in component elements (uprights, beams, and bracing) of industrial storage systems, or racks. Regarding the uprights, the sections are designed to facilitate the assembly of the system, and they have perforations along their length to connect the component elements. Owing to the high slenderness of cold-formed profiles, the elements of the system under compression are subject to local, distortional, and global buckling. In addition, the existing perforations along the length of the uprights interfere with their stability and strength.

With the growing use of industrial storage systems in recent years, it is necessary that the structural behavior of these systems and their elements be studied in more detail, so that the normative prescriptions are appropriate for the design and use of racks. In this sense, several numerical and experimental studies [1–18] have been carried out to investigate the influence of perforations on the stability and load capacity of structures.

Casafont et al. [2] performed an experimental study on rack uprights subjected to compression, with emphasis on the distortional buckling mode. The results were compared with the RMI [19], European racking code EN15512 [20], and direct strength method (DSM) prescriptions [21], showing good correlations.

Bonada et al. [8] performed a numerical and experimental analysis of the influence of the bending moment on the resistance of rack uprights subject to axial load and bending moment. The finite element model considers the residual stresses and strength enhancement induced during cold forming process. The results indicated that non-consideration of the residual stresses in the numerical model implies the need to include the initial geometric imperfections in the nonlinear analysis.

Recently, Zhao, Ren, and Qin [22] carried out an experimental study of 67 columns, with and without perforations, submitted to axial compression. The experimental results showed that the predictions obtained by the DSM [23] overestimated the load capacity, because the DSM do not consider the effect of the holes. Therefore, the authors propose a modification to the coefficients of this method.

A similar approach, with numerical study of columns without perforations, was performed by Landesmann and Camotim [14]. Four boundary conditions, different types of cross section, dimensions and

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lengths and different yield stresses were used. The paper included proposals for modifications to the DSM equations.

The objective of this work is to perform a numerical and experimental study on the influence of rectangular perforations on the behavior and strength of uprights in cold-formed specimens subjected to axial compression, with emphasis on the distortional mode. For that, it was carried out experimental tests with different perforations and upright lengths. Next, based on a calibrated numerical model, a parametric analysis using