Journal of Constructional Steel Research 71 (2012) 245–262

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Elastic stability analysis of cold-formed pallet rack structures with semi-rigid connections

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ARTICLE INFO

Article history:
Received 12 January 2010
Accepted 6 November 2011
Available online 9 December 2011

Keywords:
Finite element analysis
Cold-formed steel
Semi-rigid connections

ABSTRACT

This paper describe the three dimensional finite element modeling and elastic buckling analysis of single 2-D and 3-D frame (with semi-rigid connection) of conventional pallet racking system. Results from experimental study, effective length approach given by Rack Manufacturer's Institute (RMI) and finite element analysis of single 2-D frames of cold-formed steel pallet racking are compared. Finite element model used for single 2-D frame is further extended for 3-D frames with semi- rigid connection and results of these 3-D frames are also presented in the paper. Finite element analysis carried out on conventional pallet racks using the finite element program ANSYS with the 18 types of developed column sections. The principal aims were to find out the linear buckling load of single 2-D frames and to ascertain stability of 3-D frames of conventional pallet racking systems, made up of cold-formed sections with semi-rigid connection. Investigation into stability analysis of frames used in pallet rack structures by both experimental and finite element methods have shown that stiffening of the open upright sections using the spacer bar, channel and hat as external stiffeners will considerably increase the load carrying capacity of the frames.

1. Introduction

The behavior of industrial storage racks depends on how the individual components like beam to column connections, column bases and members perform interactively with each other. The behavior of three dimensional frames is very complex because of many parameters such as semi-rigid nature of connections, presence of significant perforations in uprights, and susceptibility to local buckling and torsional–flexural buckling. As to which method of analysis is best to solve this problem will certainly depend on the tools available to the designer. The analysis model can be as simple as using a sub-structure model such as isolating the column and using the alignment chart, or as sophisticated as using numerical methods to analyze the entire frame. With the availability of powerful computers and software, the latter approach has become more attractive, allowing more complex and efficient designs.

The analysis and design of thin-walled cold-formed steel pallet racking structure with perforated open upright section and semi-rigid joints presents several challenges to the structural engineers. Presently, for the design of these structures few code of practice like draft Australian code AS4084 [1], AISI 2001 [2], SEMA 1985 [3] and the specifications published by the Rack Manufacturer's Institute (RMI) [4] serves as guidelines for analysis and design of rack structures. Therefore understanding of the structural behavior of rack structures is very important.

Bajoria and Talikoti [5] determined the flexibility of beam-to-column connections used in conventional pallet racking system by experimentally by conducting double cantilever test on the developed connectors. They also performed full scale frame test to verify the results of double cantilever method. The experimental and finite element results are compared in the paper. Beale and Godley [6] performed sway analysis of spliced rack structures. The structures are analyzed by considering an equivalent free sway column and using computer algebra generated modified stability functions to incorporate the non-linear P- δ effects. The effect of semi-rigid beam to upright, splice to upright connections are fully included in the analysis. Each section of upright between successive beam levels in the pallet rack is considered to be a single column element. The results of the analysis are compared with a traditional finite element solution of the problem. Godley et al. [7] performed analysis and design of un-braced pallet rack structures subjected to horizontal and vertical loads. The structures are analyzed by considering an equivalent free-sway column and solving the differential equations of flexure, including P-δ effect. Initial imperfections within the frame are allowed. Results of the analysis are compared with a traditional non-linear finite element solution of the same problem. Davis [8] and Lewis [9] worked on the down-aisle stability of rack structures.

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0143-974X/$ – see front matter
doi:10.1016/j.jcsr.2011.11.002