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# Warping influence on the static design of unbraced steel storage pallet racks

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ABSTRACT

The use of thin-walled steel members has significantly increased in the last decades, especially in the field of logistics. Goods and products are frequently stored in pallet racks, i.e., in structural framed systems assembled from components manufactured from cold formed steel coils. The great convenience in using rack systems is, however, counterbalanced by a complex local and global structural behavior, often difficult to predict accurately. Owing to the light weight of the key structural components, rack design requires high engineering competence. A structural failure of these structures may result in a very great economic loss. Several research programs are currently in progress worldwide; their outcomes are expected to contribute significantly to the improvements of design rules. Standards, however, do not seem to cover adequately the modeling phase of the framed systems nor minimum requirements for the finite element (FE) analysis programs to be used for analysis. These two points are fundamental prerequisites for guaranteeing an adequate safety level in design.

A research project aimed at improving the reliability of the design rules for steel storage pallet racks and at developing suitable approaches for preliminary calculations is currently in progress. Main results of a numerical study carried out on typical medium-rise unbraced pallet racks are summarized here with the goal of investigating the key features of the warping influence on the structural frame behavior under monotonic loading; the seismic response of rack is considered in a separate paper.



## 1. Introduction

Thin-walled steel components for structural applications, formed from strips or coils by cold rolling processing, represent an important and growing area for the constructional steelwork field [1,2]. In civil engineering applications, their major use is for roof decks and curtain wall panels as well as for beams and beam-columns, which can form complete light-steel constructions for social housing and for other low-rise buildings [3,4]. As to industrial applications, cold formed steel members are frequently used to realize the skeleton frame of storage systems for goods and products, i.e., for storage pallet racks, which are the focus of the present work.

As shown in Fig. 1, pallet racks are composed by a regular sequence of upright frames, i.e., built-up laced members (Fig. 2), connected to each other in the down-aisle direction by pairs of horizontal beams sustaining pallet units. The lines of upright frames brace the storage system in the cross-aisle direction; each of them is independent between the floor level and the top from the contiguous lines, in order to keep free space for storing pallet units via automatic cranes or manual forklifts. The need to optimize the rack performance in terms of stored goods generally hampers positioning bracing systems in the down-aisle direction. Stability to down-aisle loads is, hence, provided by the sole degree of flexural continuity associated with joints.

As to key features of rack components, it should be noted that:

- Columns or uprights (i.e., the chords of the built-up laced members) have in general a mono-symmetric C lipped cross-section, which is usually completed by additional lips (Fig. 3a) located at the end of the rear flanges used to bolt lacings to uprights (Fig. 3b). Uprights are positioned with their symmetry axis parallel to the cross-aisle direction; the shear centre of the cross-section is never coincident with the centroid. Furthermore, forces transferred through lacings are usually eccentric with reference to both centroid and shear centre of the upright cross-section.
- *Beams* or *stringers* (i.e., the elements sustaining pallets) can be divided into two types, depending on whether they are sensitive to lateral-torsional buckling (Fig. 4). The selection of a cross-section shape is usually governed by the need to guarantee adequate support to pallet units.
- *Joints* (i.e., the components connecting beams to columns and column bases to the industrial floor) can be distinguished into beam-to-column joints and base-plate connections. The former

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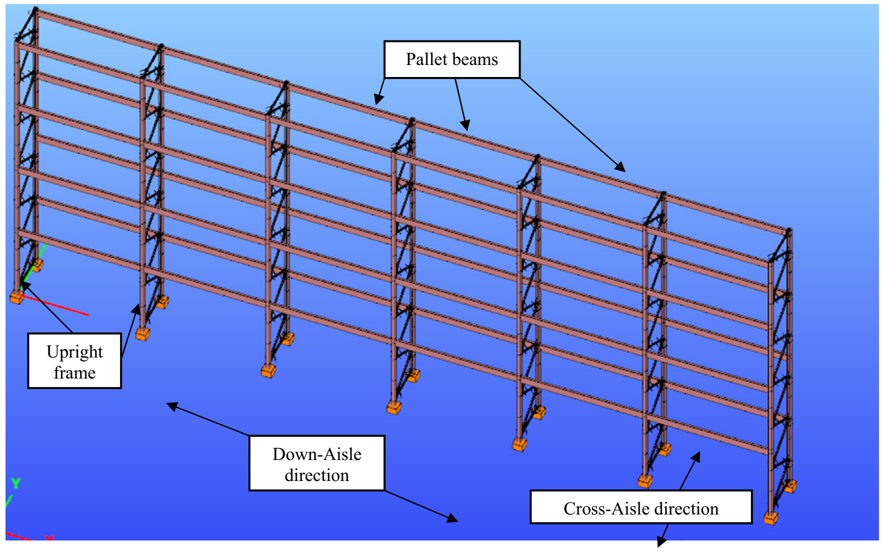


**Fig. 1.** Typical pallet rack configuration and key rack components.

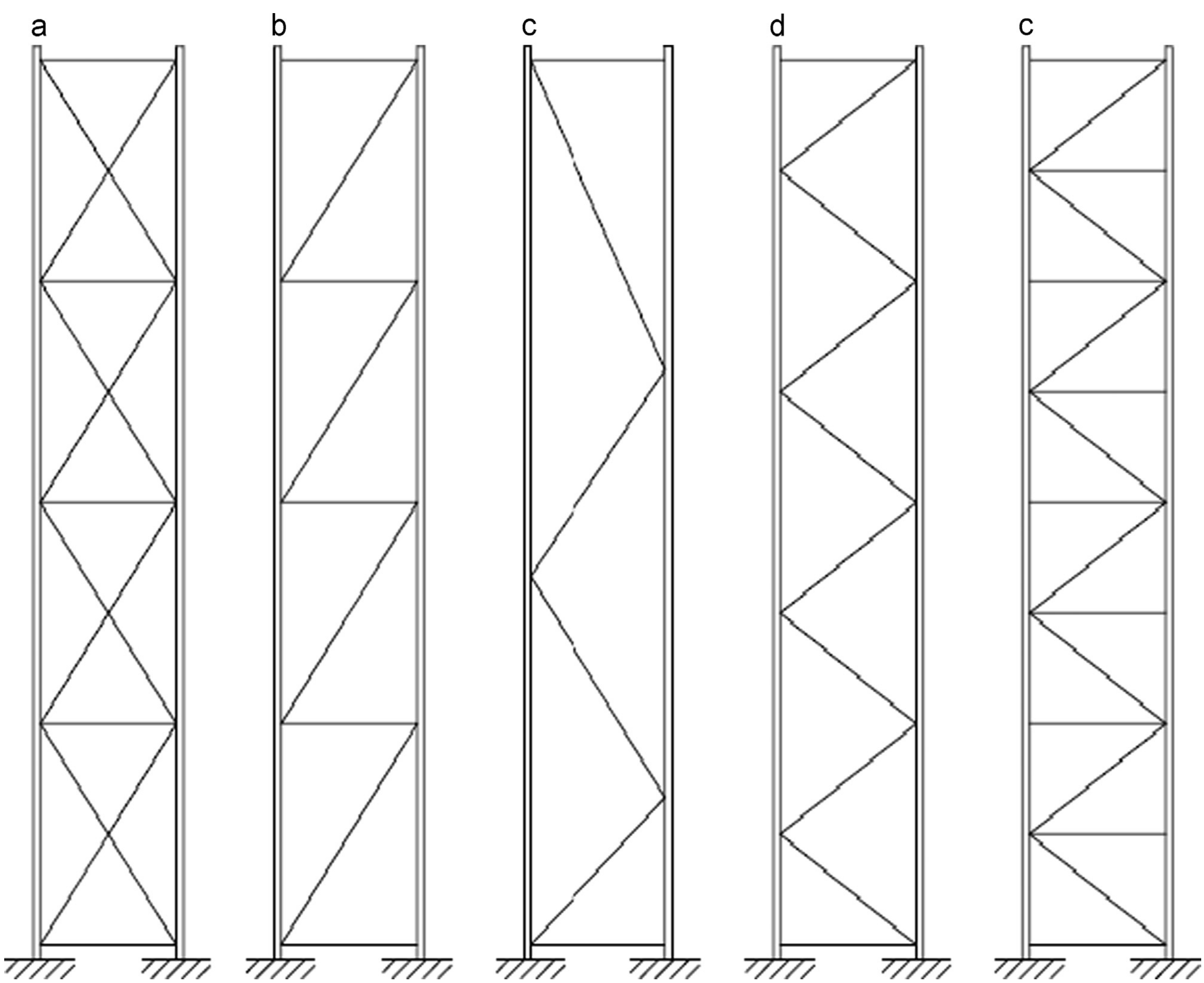


**Fig. 2.** Typical built-up laced columns used for upright frames: tension braced (a), "Z" braced (b), irregular "D" braced (c), regular "D" braced (d), and "K" braced (e) upright frames.