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Hysteretic behaviour of steel storage rack beam-to-upright boltless connections

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ABSTRACT

The hysteretic behaviour of steel storage rack beam-to-upright connections is of great importance in predicting the seismic behaviour of a rack structure, because the connections not only provide the down-aisle stability of an unbraced rack structure but also serve as a key component contributing to the structural energy dissipation capacity. An experimental study was performed to investigate the hysteretic performance of boltless connections associated with cold-formed steel storage pallet racks. A total of sixteen individual cyclic tests were conducted including the specimens with different upright profiles, upright thicknesses, beam heights and tab numbers. In this paper, the deformation patterns and failure modes, rotational stiffness and moment resistance, ductility and energy dissipation capacity, reloading and unloading behaviour are presented and discussed. The influences of crucial geometric parameters on connections behaviour under cyclic reversal loads are also investigated. The results show that boltless connections, categorised as "semi-rigid" and "partial-strength" connections, exhibit good ductility, moderate energy dissipation capacity and severely pinched hysteresis loops. Moreover, the so-called Pinching4 model is employed to characterise the hysteretic behaviour of a boltless connection, and the associated model parameters are proposed based on the test data. The proposed model of the connection will be further used in the numerical simulation of cold-formed steel storage pallet racks subjected to seismic loads. As such, this study serves as a fundamental step towards developing the Direct Design Method (DDM) for rack structures.

1. Introduction

Steel storage pallet racks are extensively used in fields such as warehousing and other short or long term storage facilitates. Generally, racks are free-standing structures, and distinct from traditional steel moment resisting frames in the following aspects [1]: Firstly, steel storage racks mainly consist of thin-walled cold-formed steel members, like complex-shaped uprights, beams and bracings. Secondly, continuous perforated upright members are commonly utilised in storage racks for the purpose of connecting corresponding beams and bracings. Thirdly, for the convenience of structural assembly and adjustment, pallet beams are generally connected to uprights through tabs or hooks in the end-connectors without welds or bolts. Fourthly, selective racks are most commonly unbraced in the down-aisle direction. These features make rack structures significantly efficient and flexible. However, due to the lack of bracing in the down-aisle direction, the stability of pallet racks is largely provided by beam-to-upright connections and column bases. Substantial research [2–9] has been conducted on the static behaviour of various beam-to-upright connections to determine their stiffness, strength, deformation patterns and failure modes. The significant influence of the connection behaviour on the overall structural behaviour is highlighted in numerous publications, e.g. [10–12]. Considering the complex nature and variable geometric detailing, current design codes for steel storage racks (Australia and New Zealand (AS/NZS4084) [13], Europe (EN 15512) [14], and North America (RMI) [15]) provide test procedures, including cantilever test and portal test, to evaluate the connection behaviour with respect to the stiffness and strength.

Seeing the recent increase in the use of steel storage pallet racks in seismic areas accessible to the public, the seismic behaviour of

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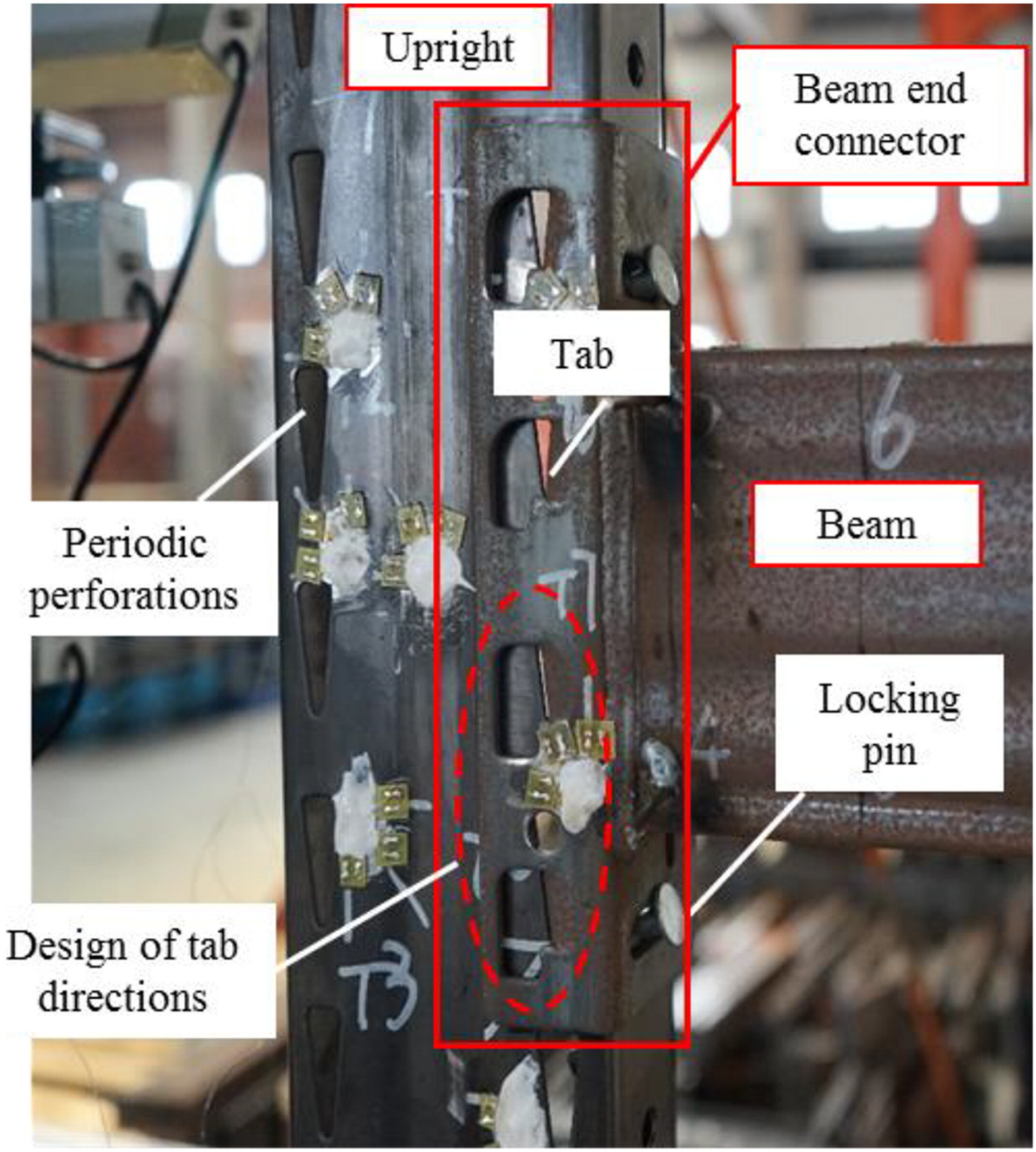

Fig. 1. Steel storage rack beam-to-upright boltless connection.

rack structures is considered to be particularly important in rack structural design. However, due to the lack of knowledge on the seismic performance of rack structures, only the RMI [15] and EN16681 [16] specifications include guidelines for seismic design. Over recent decades, several researchers have studied the seismic behaviour of rack structures, and the results of full-scale shaking