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Impact tests and parametric impact studies on drive-in steel storage racks

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ABSTRACT

Extensively used in the industry to store goods, steel storage racks are frequently subjected to accidental impact forces from operating forklift trucks. There is currently little understanding of the nature of these impact forces, leading to occasional catastrophic failures because of inadequate structural design. International racking design codes deal with impact but use an arbitrary value of impact force with no scientific justification. This paper focuses on an impact-sensitive type of storage rack, called "drive-in racks". Contrary to classical "selective racks", where pallets are stored on beams and where each single pallet is always accessible, "drive-in racks" allow the forklift truck to drive into the rack to store pallets on beam rails, one after the other, on the first-in, last-out principle. This type of design leads to slender uprights in the down-aisle direction, only restrained at the base and at the top. When subjected to an impact force, the bowing of the upright triggers progressive failure by allowing the pallets to drop through.

This paper presents experimental results obtained from tests on a complete full-size drive-in rack structure subjected to the impact of a forklift truck. Parametric impact studies using finite element analysis are also presented. Factors affecting the sensitivity of drive-in racking structures to impact are investigated and conclusions are drawn about the parameters most significantly influencing the progressive collapse of this type of rack under impact.

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1. Introduction

Steel storage racks are extensively used worldwide in industry for storing goods, mainly on pallets. They are predominantly made from cold-formed steel profiles and are competitively designed as light as possible. Due to intensive use, storage racks are frequently subjected to accidental impact forces from operating forklift trucks. There is currently little understanding of the nature of these impact forces, leading to occasional catastrophic failures.

"Selective racks", the most common type of rack, are only one pallet deep and separated by aisles, allowing each pallet to be always accessible. When storing the same goods or in space-limited and expensive places such as industrial freezers, a more economical solution to selective racks is to store the pallets on rail beams, one after the other, with no space between them. In this more compact type of rack called "drive-in racks", the forklift truck drives into the rack to store the pallets on the first-in, last-out principle as illustrated in Fig. 1. Drive-in racks are typically 3–7 pallets deep and can be numerous bays wide. Other types of racks are available in the industry and are described in [1].

To allow the forklift truck passage, drive-in racks can only be braced at the back (spine bracing) and at the top (plan bracing) in the down-aisle direction. This type of design leads to slender uprights in the down-aisle direction, only restrained at the base by the base plate assembly and at the top by the portal beam. When subjected to an impact force, the bowing of the upright may trigger progressive failure by allowing the pallets to drop through as shown in Fig. 2.

The main international racking design codes only deal with selective racks and do not mention drive-in racks. For selective racking systems, it is believed that the most severe damages are induced by an impact of the rear counterweight of the forklift truck between the floor and the first beam elevation; see the RMI [2] specification (Rack Manufacturers Institute) and the European Standard EN 15512 [3]. The RMI [2] only makes recommendations to "safeguards racks against the consequences of minor collisions" between the floor and the first beam elevation. For manually operated forklift trucks, the EN 15512 [3] uses an accidental impact force of 1.25 kN in the down aisle direction and of 2.5 kN in the cross-aisle direction but only between the floor and 0.4 m in height. On the other hand, the Australian Standard AS 4084 [4] uses an impact force applied at the most unfavourable location equal to the maximum of the unit load/15 and 0.5 kN, in both cross-aisle and down-aisle directions, for manually operated forklift trucks. However, the above impact forces are arbitrary and have no scientific justification.

The Fédération Européenne de la Manutention is currently developing a code dealing specifically with drive-in racks (FEM 10.2.07 [5]). In the current draft state, this code considers

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