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Cold-formed Steel Rack Structures

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COLD-FORMED STEEL RACK STRUCTURES

by

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INTRODUCTION

The process of moving almost all manufactured goods from the producer to the consumer involves the need for storage somewhere along the line. Nationally, a tremendous volume of materia is being stored in this process at any given time, and the cost o such storing is by no means a negligible part of the total cost t the consumer. While earlier storage and warehousing relied on ma to-order shelving and other devices, the need for improvement in storage and in handling efficiency called for increasing mechaniz tion on the one hand and increasing density of storage on the oth Both these requirements could be met only by a highly engineered development of industrial storage rack facilities. In consequence the establishment of the storage rack manufacturing industry as a identifyable branch of the nation's multi-billion dollar materials handling industry occured during the early 1960's.

The requirements for a storage system vary widely with the nature of the storage situation. However, a general criterion is the ability to store as much material as possible in a given volum

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while providing sufficient and convenient access for efficient moving of the goods. Warehouses are mostly used for storing a multitude of different kinds of goods, and the storage system must be versatile and adjustable. In addition, again because of changing needs over the years, it is often desirable that such installations be readily demountable and capable of reassembly.

Cold-formed steel construction, because of its versatility in providing solutions to these problems is by far the most common type of construction for storage systems.

Because of the special nature of storage structures, their design presents many problems that cannot be handled routinely within existing design specifications. Some of these special problems will be discussed below. Recognizing the need for industry-wide uniform design criteria and practices, the Rack Manufacturers' Institute published their first design standards in 1964.

The need for improving these standards was realized by the industry, motivated in part by a tendency among building officials to promote inclusion of rack structures in building codes. In consequence, the Rack Manufacturers' Institute, in consultation with the authors of this paper, prepared the "Interim Specification for the Design, Testing, and Utilization of Industrial Steel Storage Racks," published in 1972. This document will be referred to hereafter as the Specification. A supplement to the Specification is being prepared and will be available shortly. The Specification carries the "interim" designation because the engineering and test evidence on which it is based was limited by time constraints.

Consequently, a consciously conservative approach was taken. It is possible that some of its provisions can be liberalized in later expanded editions, on the basis of more complete evidence. Work to that end is now underway.

TYPES OF RACK STRUCTURES

Pallet Racks

In general pallet racks are used for relatively low density storage or in situations where all the goods must be accessible at all times. The vertical load carrying elements consist of "upright frames." An upright frame, in terms of the rack industry, is an assembly of two posts truss-braced against each other. The posts are in general cold-rolled lipped channel sections. The upright frames support the horizontal "shelf beams" which are perpendicular to the planes of the upright frames. The goods are usually stored on wooden or metal pallets which are placed by fork-lift trucks on the shelf beams. Horizontal stability in the direction of the shelf beams is provided either by rigid or semi-rigid frame action of the shelf beams and posts, or by x-bracing in the rear plane. Quite often two rows of pallet racks are tied back-to-back, thus resulting in a structure that is more stable against overturning and also provides a higher density storage system. Typical pallet rack installations are illustrated on Figs. 1 and 2. The maximum height of pallet racks, determined by vertical reach of fork-lift trucks, is at present about 30 feet.

Drive-in Racks

When high density storage is required and access to all the goods at all times is not needed, the Drive-in Rack system as shown on Fig. 3 may be used. Usually, the upright frames are connected at the top, thus forming a series of portal frames. At appropriate elevations, as the storage situation requires, arms are connected to the posts. These arms, in turn, support the horizontal rail beams which are parallel to the planes of the upright frames. Pallets are placed on the rail beams, again by fork-lift trucks. Thus, rows of uprights provide rows of storage spaces and several pallets can be stored in each row. In this type of rack system the plane of the innermost posts has truss- or x-bracing perpendicular to the planes of the upright frames. The maximum height of the rack is again determined by the vertical reach of the fork-lift truck.

Drive-thru Racks

This type is similar to drive-in racks with the exception that the bracing of the innermost posts is omitted as illustrated on Fig. 4. This provides access to the stored goods from both ends of all storage rows. Drive-thru racks, when not connected to an external support, behave as portal frames. In contrast, drive-in racks rely for horizontal stability in part on the same portal frame action, but also on the previously described braced plane and the rail beam assemblies cantilevering out from that plane.

Stacker Racks and High Braced Pallet Racks

When storage requirements necessitate a rack system higher than those discussed above, a stacker rack or a high braced pallet rack may be used. The stacker rack is basically a one-deep high rise drive-in rack. The pallets are placed on the rail beams by means of a stacker crane whose operation is often highly automated.

Current maximum height for stacker racks in the U. S. is about 110 feet. High braced pallet racks are a high rise version of simple pallet racks with additional bracing for horizontal stability. An example of high braced pallet racks is illustrated on Fig. 5.

Other Types of Racks

In addition to the racks discussed above, there are several other types, such as Cantilever Racks, Stacking Sectional Racks, etc. These types, as well as Rack Buildings, are not included in the scope of the Specification. In a rack building not only the stored goods but also roof and walls are supported by the rack structure.

SPECIAL PROBLEMS

Loads

Vertical Impact: Provisions for the vertical impact of the pallet as it is placed on the rack are given in the Specification.

Horizontal Loads: Earthquake and wind, where applicable, and accidental horizontal loads due to collision by fork lift trucks are among the horizontal design loads. In addition, according to the Specification, racks are to be designed for a horizontal force that is a percentage of the vertical loads on the rack. This is to insure sufficient horizontal stability and rigidity for satisfactory and safe service in case of uprights which are not ideally vertical, floors which slant or settle unevenly, etc. Collision of the fork-lift trucks with posts is a serious threat to the rack. The Specification requires that even if such a damaged post loses all its load carrying capacity, the rack structure should not collapse.

Flexibility

Rack structures are in general much less rigid than usual building structures. However, horizontal and vertical deflections need to be held within strict tolerances for safe pallet handling. In drive-in, drive-thru and stacker racks the distance between the rail beams depends directly on the deflections of the structure, and this distance determines whether or not the pallet is resting safely on the rail beams. The stacker racks have special deflection tolerances due to stacker crane operation requirements. In general, deflections of the rack structure need to be computed quite accurately for a variety of loading cases. The deflection computations should include the effects of any looseness of connections as discussed below.

Connections

In almost all types of racks, the elevations of horizontal load carrying members need to be readily adjustable. In addition, as discussed above, it is often desirable that a rack installation be demountable and capable of reassembly. As a result, a variety of types of special mechanical connections, some of them quite ingenious, are used in rack structures. It should be noted that such adjustable connections more often than not lead to a certain amount of looseness of the joints. This feature of rack structures is quite different from usual building construction. Special considerations to account for looseness of joints should be included in the analysis of rack structures. Because of the complex nature of connection configurations, which differ among different manufacturers their looseness and strength can usually be determined only by The specification standardizes these testing procedures to the maximum possible extent.

Friction Effects

Under certain circumstances the friction between the palle and rail beams may help to stabilize drive-in and stacker racks The specification recognizes that by means of a rational analys based on test values of friction, the beneficial effects of fri may be utilized. However, in earthquake zones utilizing the fri in such a manner would not be advisable.

Strength of Posts

In general, the main vertical load-carrying members, namely the posts, have significant perforations to accommodate the adjustable rack connections. These perforations influence the loc stability and, hence, the overall stability of the posts to a si nificant extent. Based on the results of an experimental study, design method for evaluating the influence of perforation has be developed by the authors. In brief, it involves obtaining the f factor Q by stub column tests and using it in a modified version the current A.I.S.I. Specification column design procedure. The modification involves reducing the A.I.S.I. Specification values by up to 15 percent for certain ranges of the slenderness ratio. This reduction was shown to be necessary by the experimental stud

Other Features

In addition to those discussed above, several other features are included in the Specifications. Many of these are concerned special frame analysis and design considerations, relating specifically to the unusual type of framing employed in rack structures.

SUMMARY

The vast demand for large-scale mechanized storage of industrial goods has led to the formation of a special rack manufacturing industry. It mass-produces a variety of types of industrial storage racks, now ranging in height to 110 ft. Because of the particular requirements on storage rack configurations, cold-formed steel construction with its versatility of shape is the most common medium for such structures. The Rack Manufacturers Institute, in consultation with the authors, has developed the "Interim Specification for the Design, Testing and Utilization of Industrial Storage Racks," published in 1972. The paper briefly describes and illustrates the various types of industrial storage racks and some of the design features covered in the Specification. Continuing experimental and analytical studies, now underway, will lead to further refinement and possibly some liberalization of the Interim Specification.

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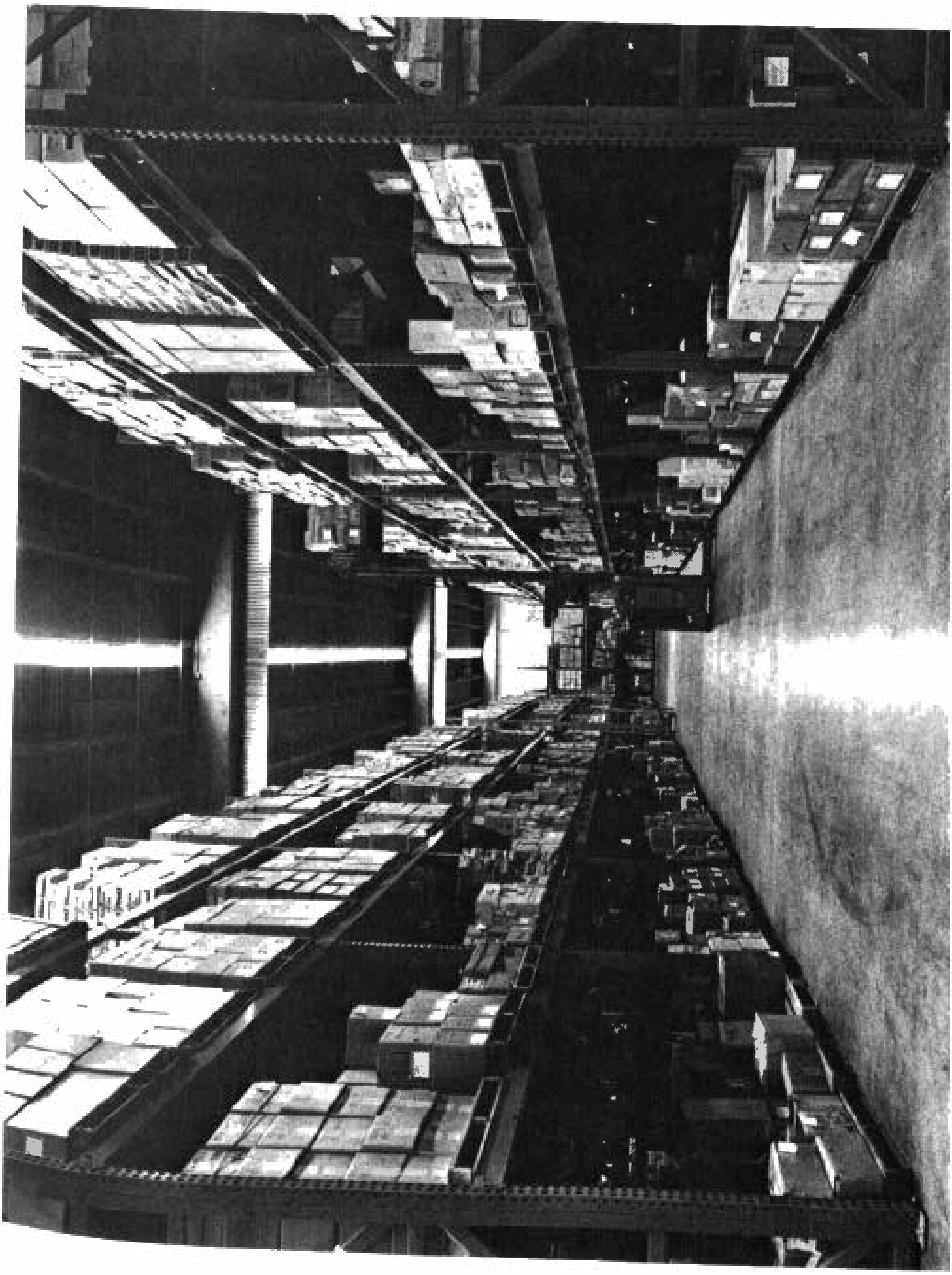
STEEL RACK STRUCTURES



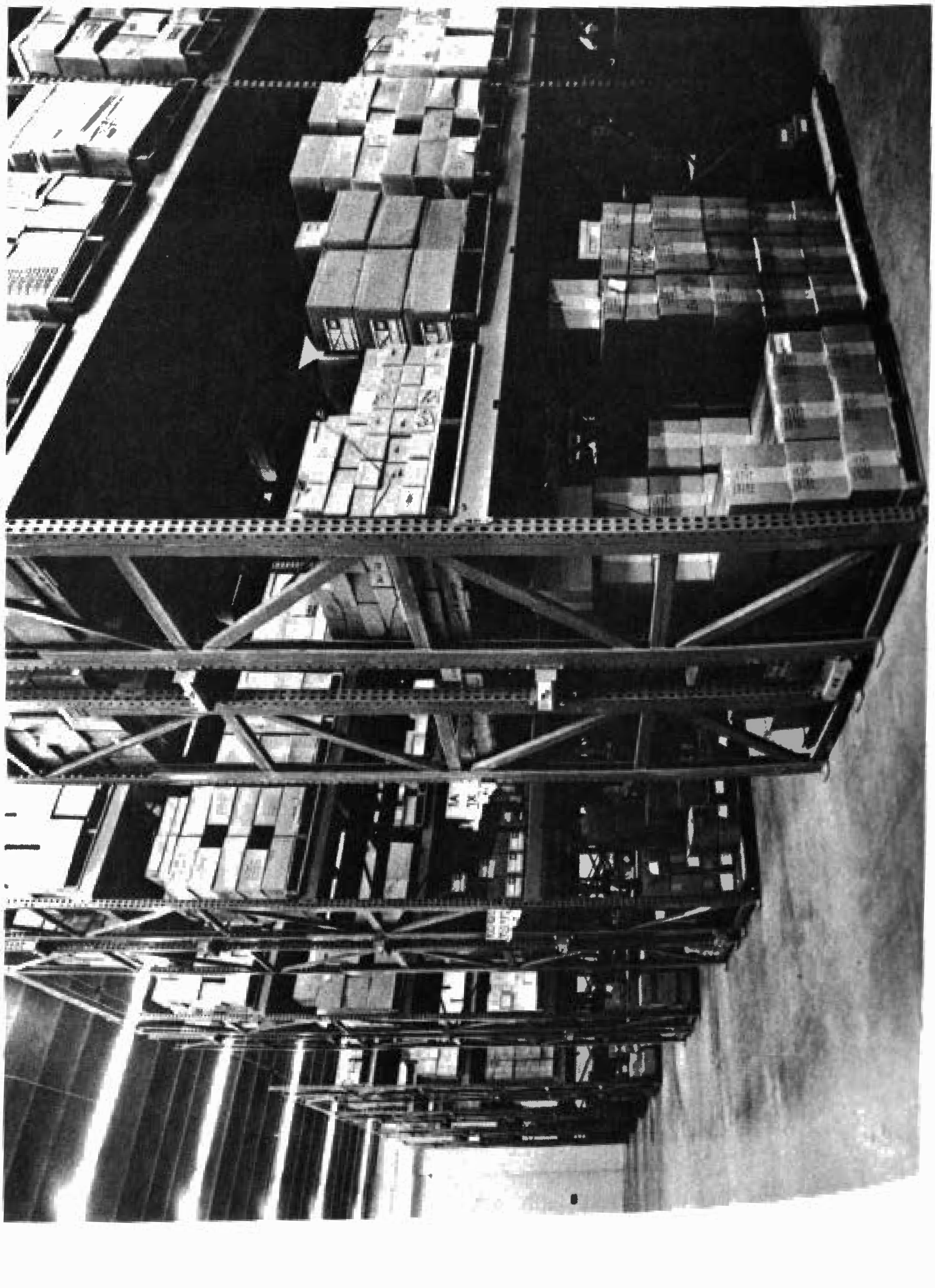


FIGURE 2

STEEL RACK STRUCTURES

FIGURE 3

FIGURE 4

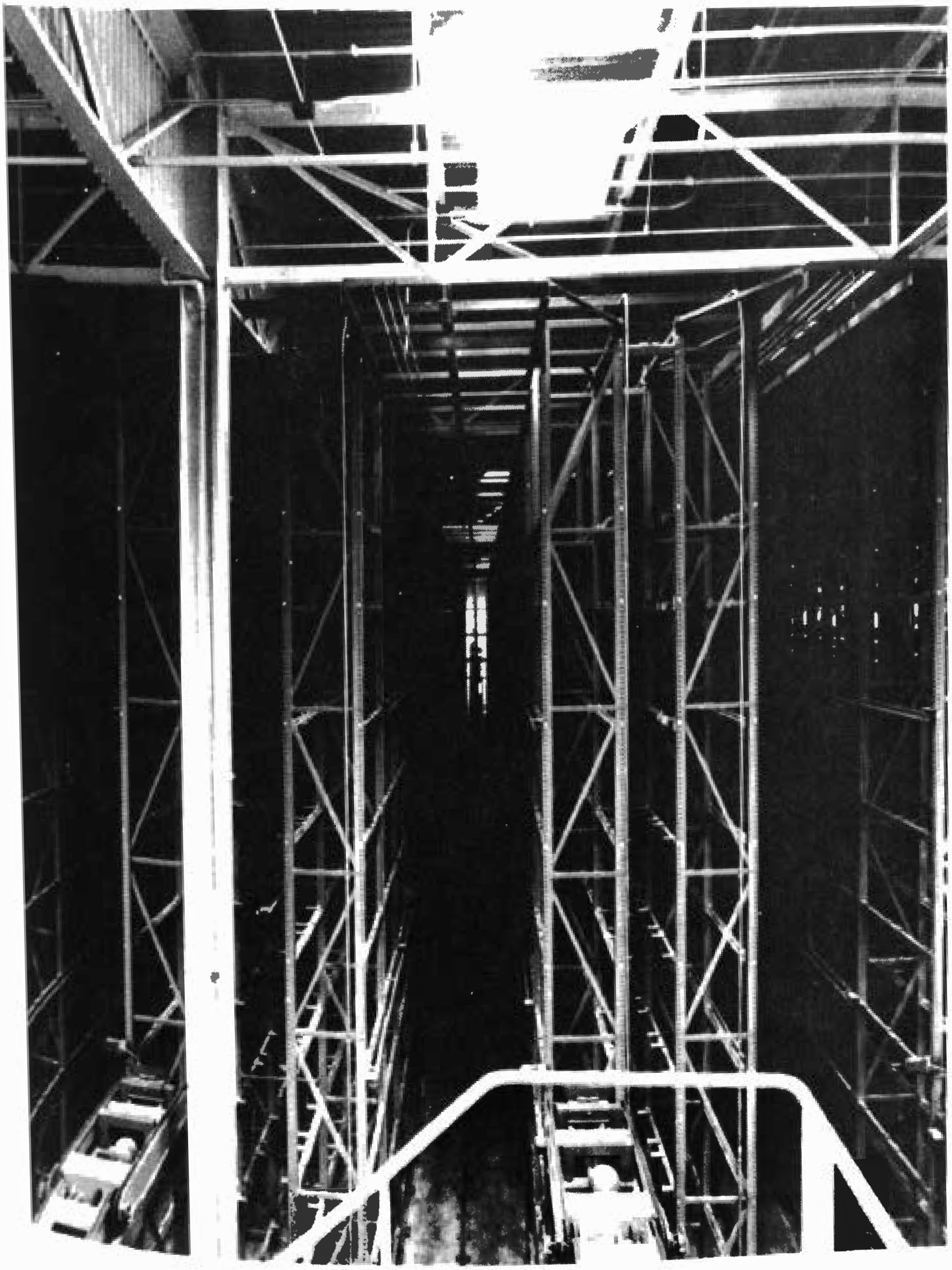


FIGURE 5