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Progress Report on Cold-formed Steel Storage Rack Design

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PROGRESS REPORT ON COLD-FORMED STEEL STORAGE RACK DESIGN

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INTRODUCTION

Rack structures are important applications where the versatility and economy of cold-formed steel construction is demonstrated. The authors have described this type of construction and the special problems that arise in the design of such structures in Ref. 3.

From the structural design point of view, rack structures have several features that are quite different than those encountered in usual building construction. The latest edition of the design specification (2) was prepared by the Rack Manufacturers' Institute in consultation with the authors and published in 1972. Because of the time constraints this specification had to be prepared on rather limited engineering and test evidence. For this reason, a consciously conservative approach was taken and the specification is designated as "interim".

The authors have been conducting research to refine and liberalize the provisions of the specification. Their research includes large scale testing at Cornell University to obtain quantitative and qualitative information on the behavior of cold-formed steel pallet racks. Currently, the evaluation of these tests as well as further tests on drive-in and drive-through racks are in progress.

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TESTS ON PALLET RACKS

General

In general pallet racks are used in situations where all the goods must be accessible at all times or where multiple tiering of pallet loads is not feasible. 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. The maximum height of pallet racks, determined by vertical reach of fork-lift trucks, is at present about 30 feet.

In the first phase of the current investigation eight full scale pallet rack assemblies were tested. Racks of three different manufacturers were involved in this program. In addition to full scale assembly tests, several component and subsidiary tests were conducted.

Rack Assembly Test Setup

All the assemblies tested had three beam levels and two bays. The height of the rack structure was about 15 feet for 6 tests and 17 feet for two tests. Each bay was 90 inches wide. The depth of the racks was 42 inches.

The vertical load is applied by steel tanks resting on pallets placed on the rack. These are filled with water in increments.

Additionally cast iron weights are hung from the tanks. Alternate span loading was also used either by filling the tanks in alternate spans or by lifting the tanks and hung weights off the rack by means of hydraulic jacks. Lateral loading was applied by means of hydraulic jacks.

The tanks were tied to an overhead safety frame by loose cables. In this manner, when a rack collapsed, the load was suspended from the overhead frame.

Several strain gages were used at various locations. Deflections were measured by dial gages and by scales that were read by transits.

Test Results

The racks tested could be classified into two groups from the point of view of their connections. These are racks with connections that involve special hook and slot devices and racks with bolted connections. The former type will be referred to as a mechanical connection.

Photographs of some of the tested racks are given in Figs. 1 through 8. An overall view of a tested rack with mechanical connections is given in Fig. 1. A close-up view of the center upright of the same rack is shown in Fig. 2. This rack was subjected to a combination of vertical and horizontal forces. In all the tests with combined loading, the horizontal forces at each load level was 1.5% of the vertical loads at that level as specified in the RMI Specification. Failure was by side sway and collapse of posts, as can be seen in the photographs.

An overall view of a tested rack with bolted connections is shown in Fig. 3. The separate rack on the right hand side was used to jack up the loading on the lower right hand beam to study alternate span loading conditions. Fig. 4 illustrates the connection detail for this rack. The distortions of the post at a beam connection level can be observed in Fig. 5. In this test the failure was caused by yielding and collapse of the beams. This is noticeable in Fig. 3 where the two left bottom tanks are inclined toward each other and touch along their top edge due to the beam deflection.

Another tested rack with mechanical connections is shown in Fig. 6. This rack was subjected to only vertical loads. Fig. 7 shows a close-up of the center upright of this rack. The failure was again by side sway of the entire frame and collapse of the posts.

The same type of rack as shown in Figs. 6 and 7 was subjected to a combination of vertical and horizontal loading. The tested rack is shown in Fig. 8.

The evaluation of test results is currently in progress. However, the following general tentative conclusions can be stated. From the strain and deflection readings it was seen that under vertical loads the beams in a rack behave primarily as simply supported. On the other hand, frame action is observed for lateral loads. Preliminary computations indicate that the failure of a rack can be predicted by the use of established interaction formulas provided that proper effective lengths are used.

TESTS ON DRIVE-IN RACKS

Currently a test program on drive-in racks is in progress. A description of drive-in racks is given in Ref. 3. So far two drive-in racks were tested. One was subjected to only vertical loads and the other to a combination of vertical and horizontal loads. The assemblies tested are 22 feet high, 11.5 feet wide and 16 feet deep. It is planned to test two more drive-in rack assemblies.

TORSIONAL FLEXURAL BEHAVIOR STUDIES

In most rack structures the posts are of singly symmetric open cross-section. These sections are subjected to a combination of axial load and a bending moment about the axis of symmetry. Neither the R.M.I. Interim Specification (2) nor the A.I.S.I. Specification contain provisions for this loading case. For this reason, the first author has prepared a computer program to analyze the stresses and deflections of simply symmetric sections eccentrically loaded outside the axis of symmetry. The program is based on an energy solution. An experimental program for the verification of the computer program is contemplated.

SUMMARY

A testing program as well as the associated analytical studies are in progress to refine, improve and modify the existing design specifications for cold-formed steel racks. It is expected that the results will be incorporated into the next edition of the R.M.I. design specification.

ACKNOWLEDGEMENT

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APPENDIX I. - REFERENCES

1. "Specification for the Design of Cold-Formed Steel Structural Members", 1968 Edition, The American Iron and Steel Institute, Washington, D. C.
2. "Interim Specification for the Design Testing and Utilization of Industrial Steel Storage Racks", 1972 Edition, Rack Manufacturers' Institute, Pittsburgh, Pa.
3. Peköz, T. and Winter, G., "Cold-Formed Steel Rack Structures", Proc. Second Specialty Conference on Cold-Formed Steel Structures, 1973, University of Missouri, Rolla, Mo.

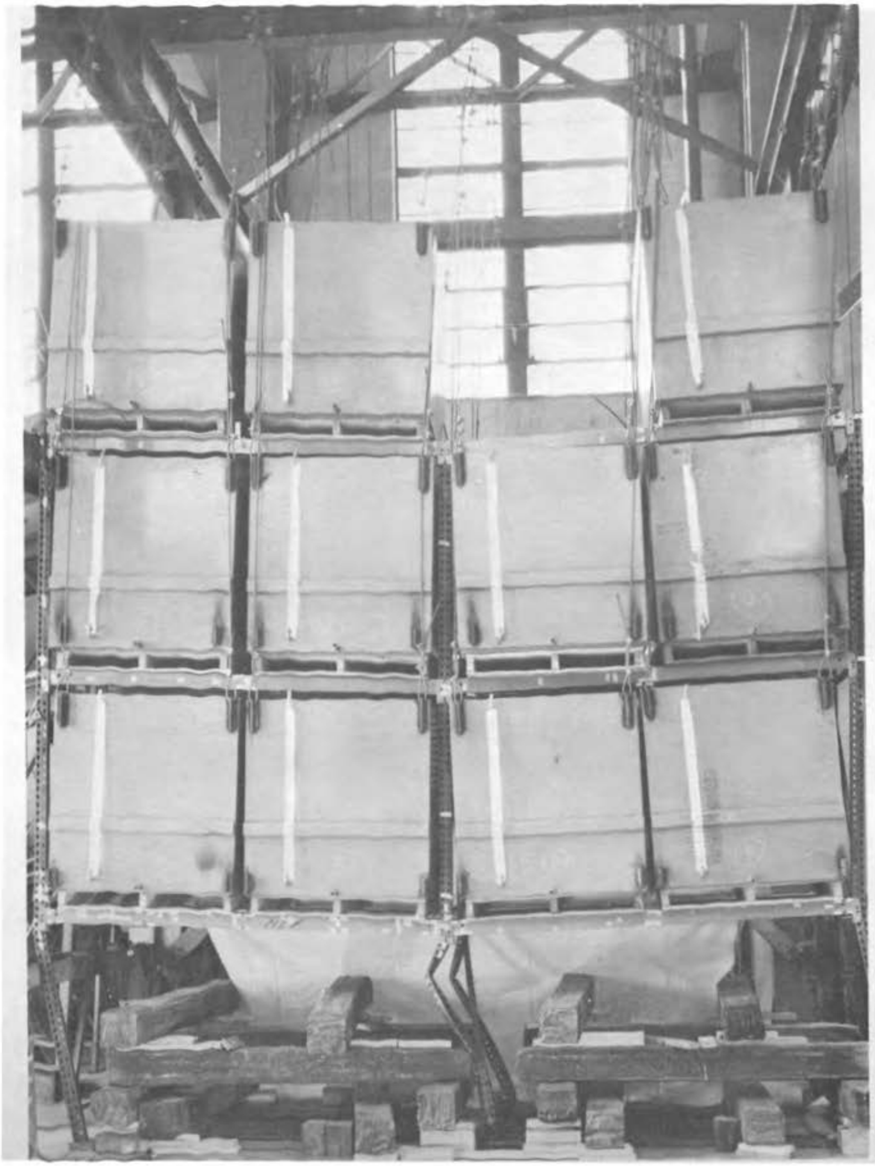

Fig. 1 Overall View of Tested Type A Rack - Vertical and Horizontal Loading

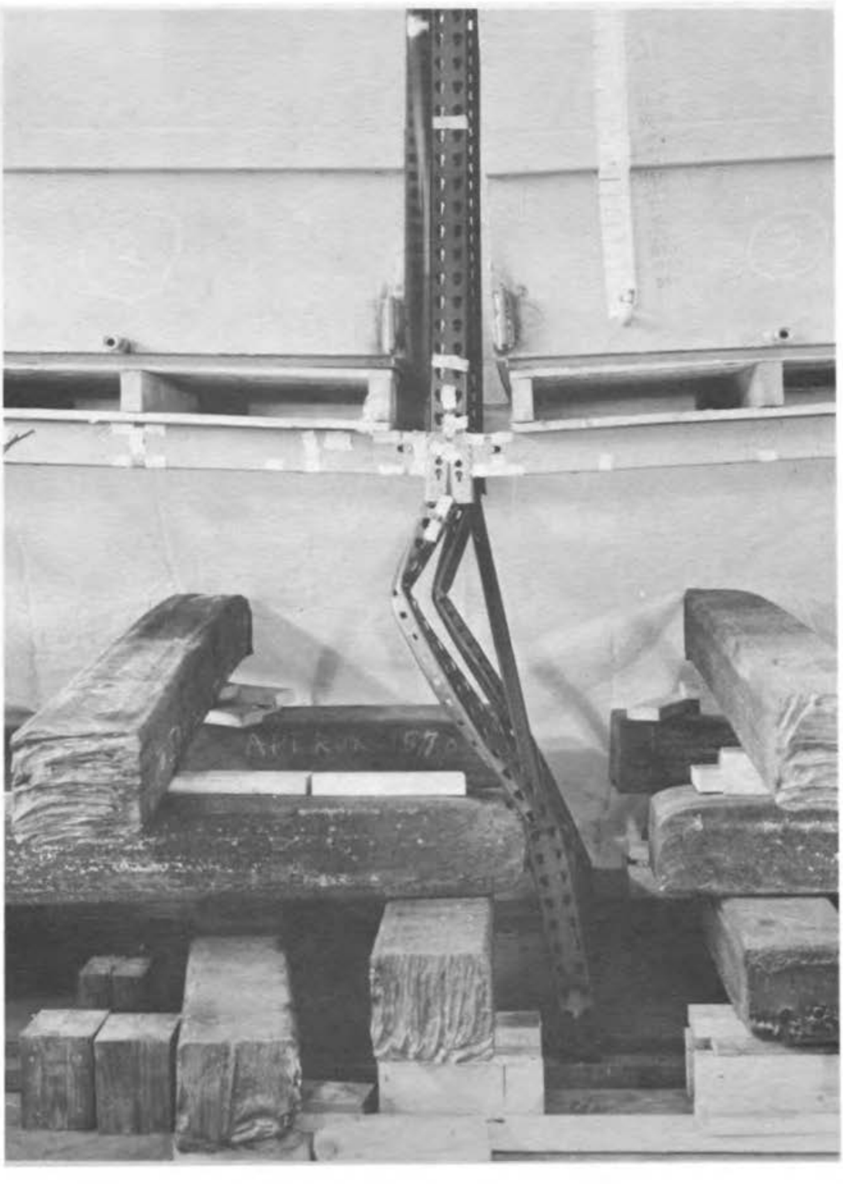

Fig. 2 Close-up View of the Center Upright of Tested Type A Rack

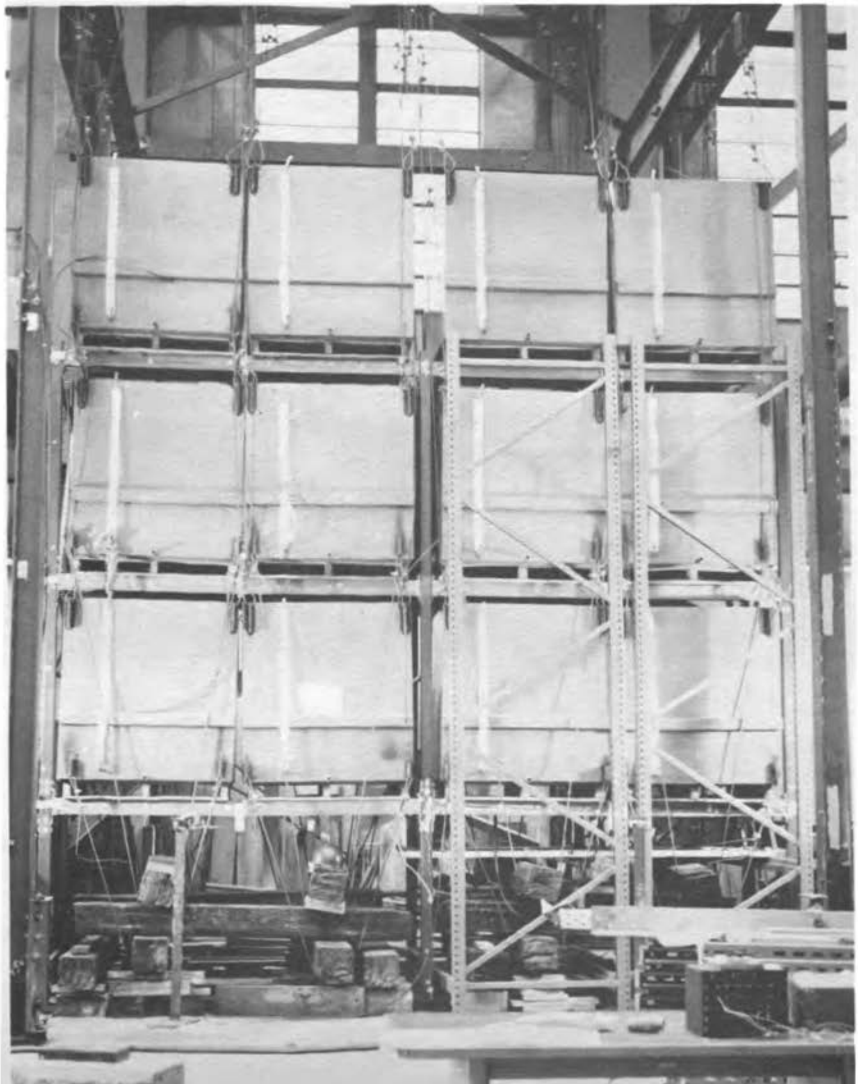

Fig. 3 Overall View of Tested Type B Rack
- Vertical Loading Only

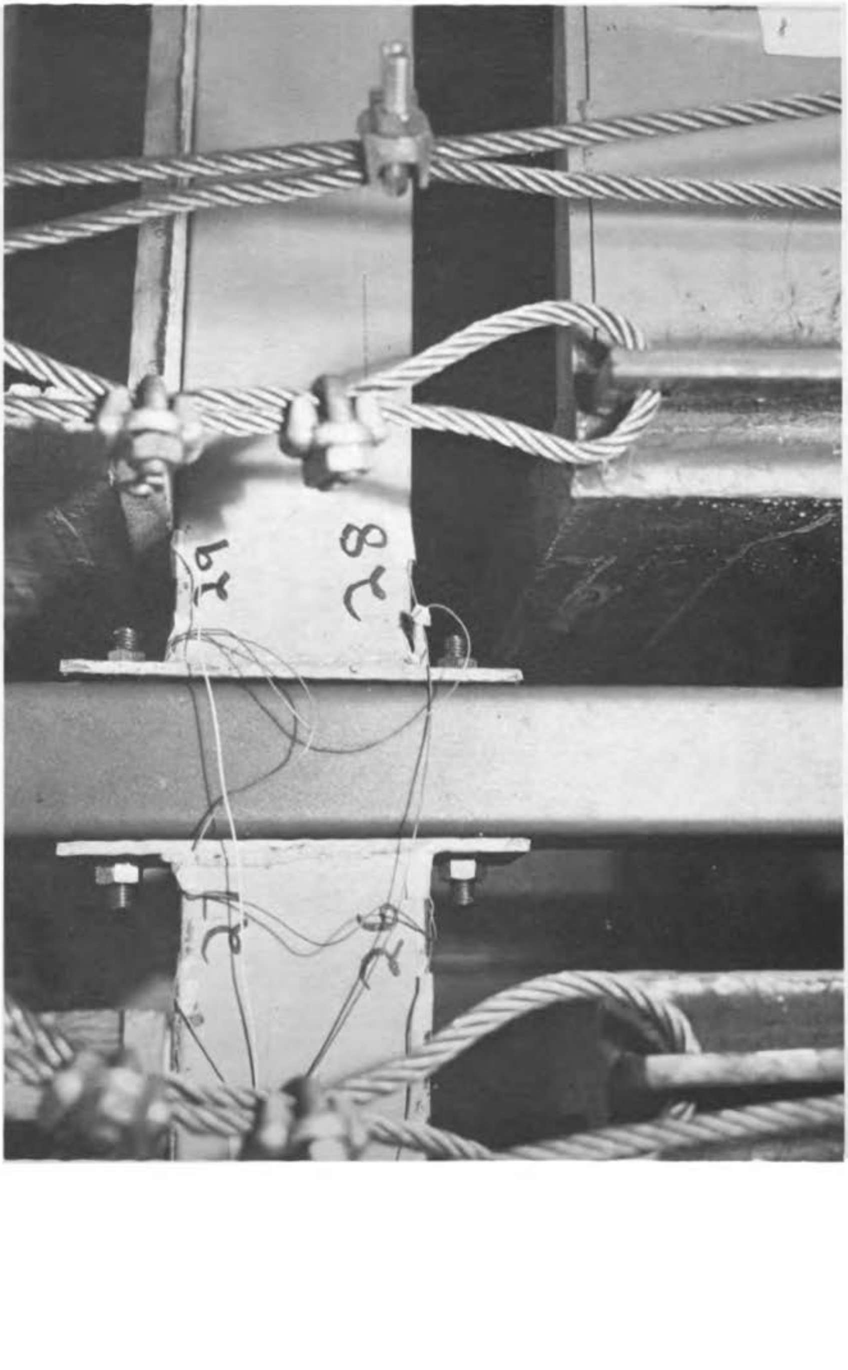

Fig. 4 Connection Detail of Type B Rack

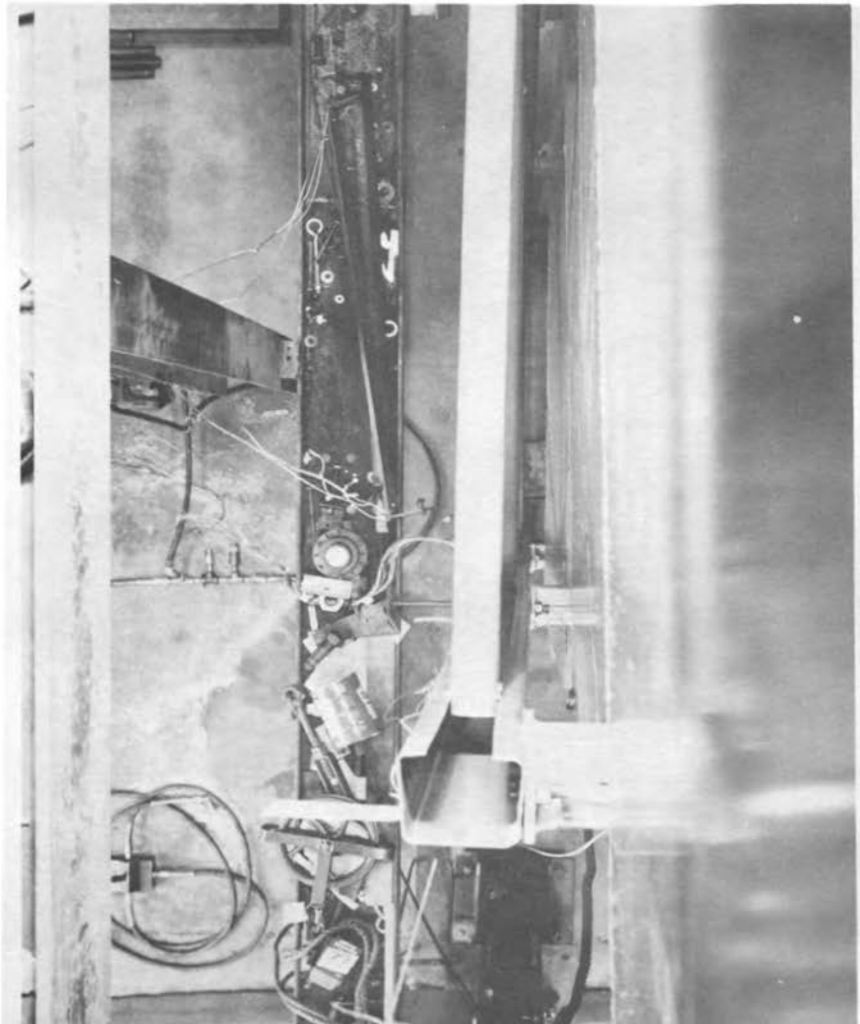

Fig. 5 Top View of a Post of Type B Rack

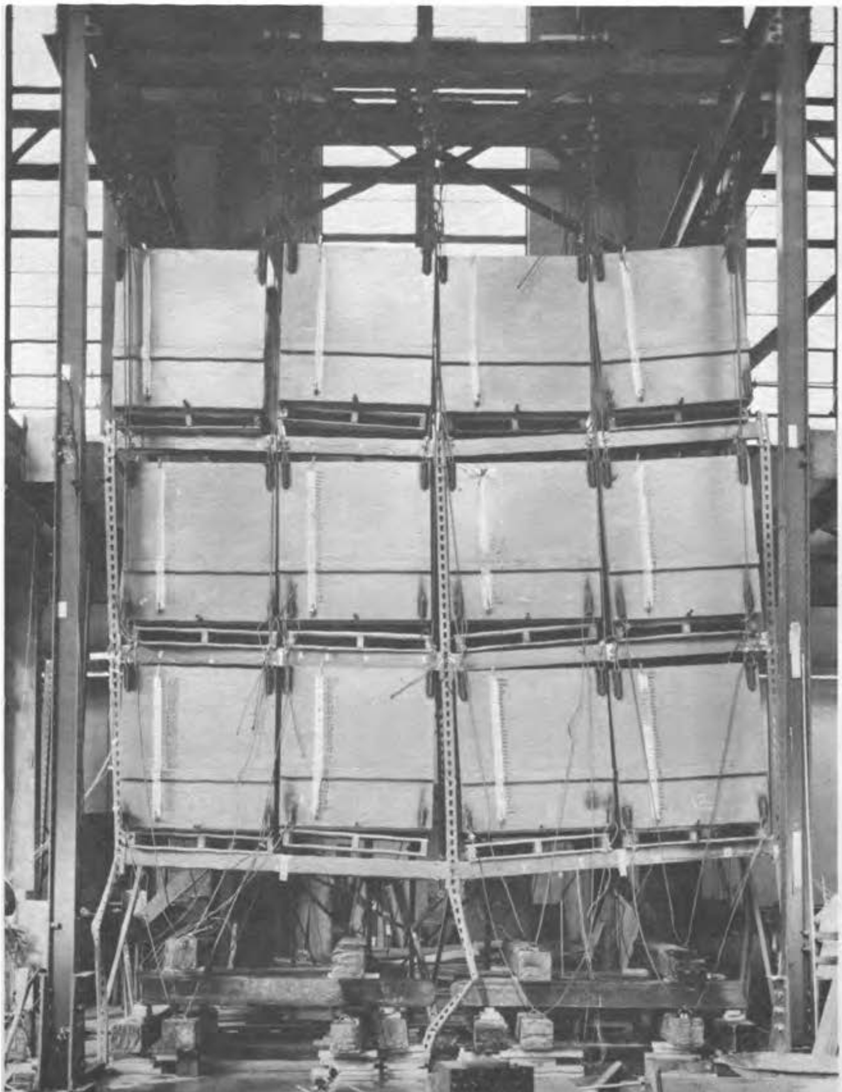

Fig. 6 Overall View of Tested Type B Rack
- Vertical Loading Only

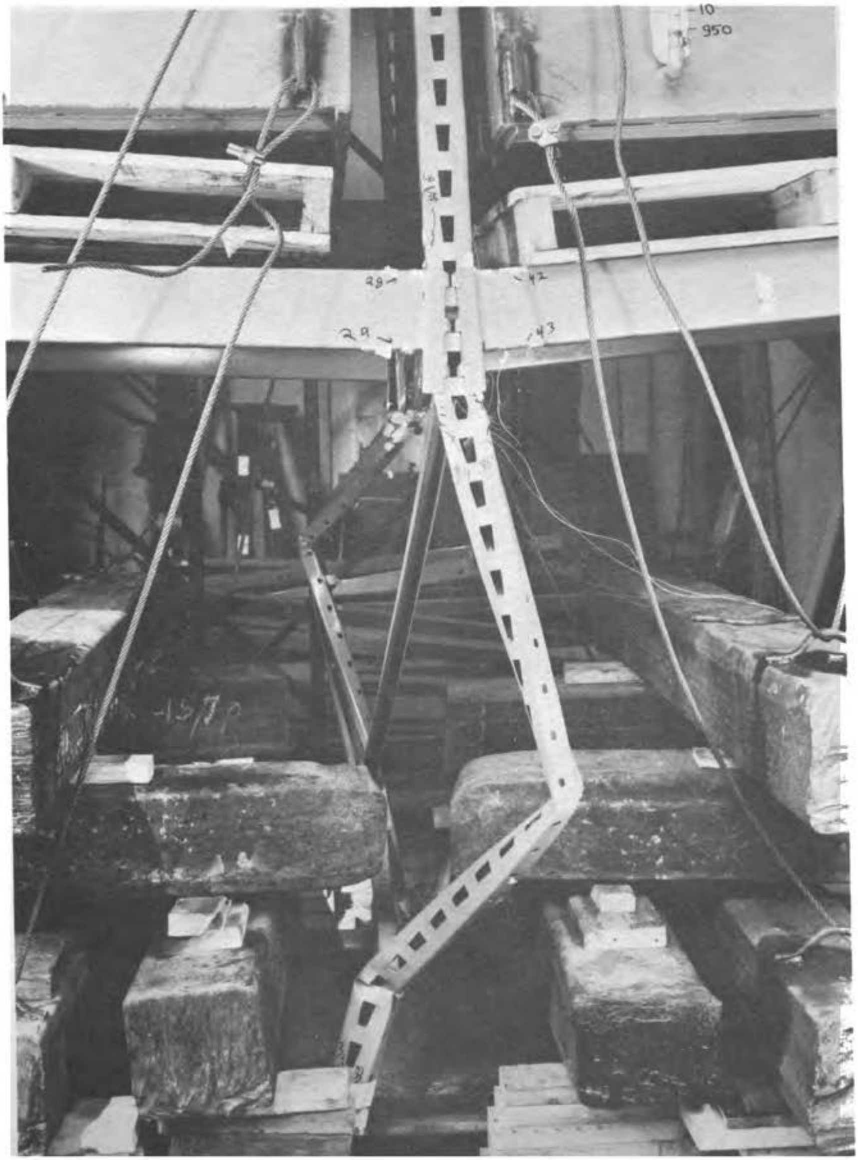

Fig. 7 Close-up View of the Center Upright of Tested Type B Rack - Vertical Loading Only

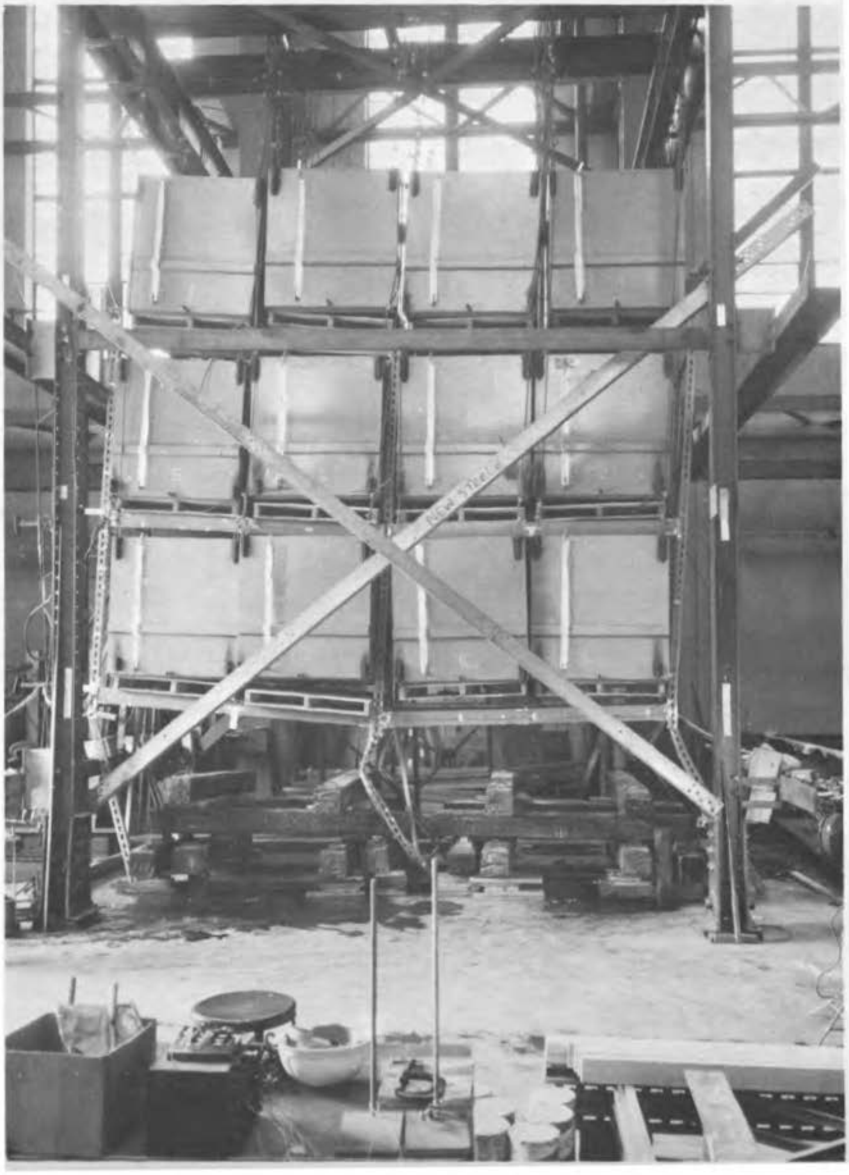

Fig. 8 Overall View of Tested Type B Rack
- Vertical and Horizontal Loading