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Optimization of Steel Storage Rack Column and Its Performance Analysis

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ABSTRACT

The main aim of the project is to perform a finite element analysis on steel storage columns. Rack systems for pallet storage are important industrial structures by number and commercial value, yet they have been considered only recently in studies aiming at defining practical design rules for their safe use. These structures are always composed of metal elements. The fabrication of rack structures constitutes, indeed, an important application of cold-formed steel products. The need for continuously loading and unloading the shelves in service has induced designers to avoid bracing elements in the longitudinal direction of the racks. Therefore in many cases, lateral stability in this direction is ensured only by the connections between beam and column and by the constraint offered by the base of the columns. ANSYS used for the model development and analysis presented in this paper. The main requirements for a finite element (FE) model of storage rack frames is to have the flexibility to represent the complex cross-section geometries of the members, and the ability to assign semi-rigid behavior to joints and to take into account the effect of local, distortion and flexural-torsional buckling in determining the ultimate capacity of the structure and optimization.

Keywords: ANSYS; finite element, steel storage rack column, lateral stability.

1. INTRODUCTION

Cold-formed steel sections have become usual in many kinds of structures, and consequently much research has been done to understand their behavior and to develop design procedures. Among these structures, there are the storage systems, usually called racks, widely used throughout the world for storing materials in distribution companies. These systems provide high storage density, allowing the storage of a great amount of products in reduced areas, due to their vertical character. Besides, they also allow great Accessibility to the stored materials. Many companies are using these systems to store their product in large scale.

There are several commercial models that fit to the conditions demanded for each product to be stored in the available room. These models vary from simple shelves to automated structures of more than 30 m height. Among these several models, it is worth mentioning the Pallet and Drive-in Systems. The Pallet rack is the most common storage rack used in Brazil. The Drive-in model presents peculiar structural concepts: the absence of transversal beams to allow trucks to move inside the structure and the presence of holes on the columns to facilitate assemblage. Shows a Pallet and a Drive-in rack in operation.

The Brazilian Association of Handling and Logistic has introduced some recommendations for designing rack systems that, in the future, will be used in a Brazilian code. This work presents an analysis of typical columns of commercial Brazilian racks, using the commercial finite element software ANSYS. The results are compared with experimental data, based on prescriptions of RMI and from previous work.

Fig. 1 Steel Storage Rack Column

II. OBJECTIVES AND SCOPE

A. Column Base

Storage rack stability depends significantly on the conditions of the column bases. The RMI specification uses the following base fixity expression, for the ratio of the moment with respect to the corresponding rotation of the base to account for the semi-rigid nature of the connection of the column to the floor as a method for finding the moment-rotation relationship by analyzing the behavior of such anchorages in five different stages starting with a trapezoidal stress distribution in the concrete floor under the base plate and ending at the failure of the anchor bolts. The RMI specification considered only the first stage.

The connection between the column and the floor could be represented in an analytic frame model either by a tensional spring or by inserting an equivalent floor beam between the column bases. The stiffness of the equivalent floor beam that would provide the same restraints as Eq. could be found from basic structural analysis. Consider a beam element in with its two ends identified as a and b.

III. THE RACK COLUMN

The analyzed column is made of cold-formed steel, where the cross-section shape is a thin-walled “rack”. One of these cross sections and the range used for the identification of its parts are presented in Fig 3.It has as particularity rear flanges that allow fitting the braces, making it easier to assemble the structure.

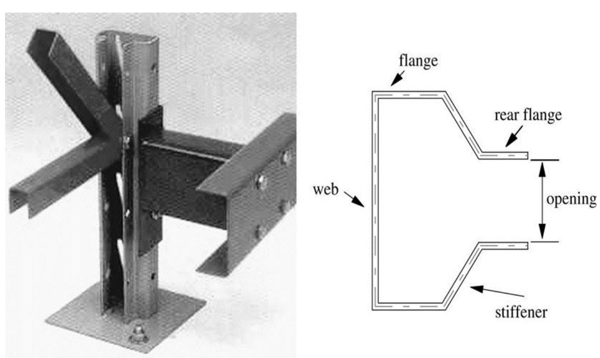


Fig. 3 Connections in the column, “Rack” cross-section type and nomenclature.

A. Design Procedures

The main characteristic of the column, however, is the existence of holes along its height that allows fitting the connections of braces and other structural elements. These holes influence the structural behavior of the column and therefore, should be taken into account in the project analysis. To quantify the influence of the holes on the load capacity of the columns.

All computations for safe loads, stresses, deflections, and the like shall be made in accordance with conventional methods of structural design as specified in the AISI [1] for cold-formed steel components and structural systems and the AISC (2005) [2] for hot rolled steel components and structural systems except as modified or supplemented by this specification. In cases where adequate methods of design calculations are not available, designs shall be based on test results obtained in accordance with this specification or Section F of the AISI [1]. No slenderness limitations shall be imposed on tension members that are not required to resist compression forces under the various load combinations specified in RMI Section.

B. Design of steel elements and members

- The effect of perforations on the load-carrying capacity of compression members is accounted for by the modification of some of the definitions of the AISI [1] and the AISC [2] as described below.

- Cold-formed steel members
- Properties of sections
- Exceptions to the provisions of the AISI [1] for computing the section properties are given in RMI Sections. Except as noted all cross-sectional properties shall be based on full unreduced and unperforated sections considering round corners.
- Flexural Members
- Se = Elastic section modulus of the net section times
- (0.5 + Q /2) for the extreme compression fiber.
- Sc = Elastic section modulus of the net section for the extreme compression fiber times

$$1-\frac{(1-Q)}{2}\left(\frac{F_c}{F_y}\right)^Q$$

- The value of Q shall be determined according to RMI. Section properties j, ro, and Cw shall be permitted to be computed assuming sharp corners. Inelastic reserve capacity provisions of the AISI [1] Section C3.1.1 (b) shall not be considered for perforated members.
- Concentrically Loaded Compression Members
- Effective Area

$$A_e=\left[1-(1-Q)\left(\frac{F_n}{F_y}\right)^Q\right]A_{net\,min}$$

- Ae = Effective area at the stress Fn determined according to Section 4.1(RMI) when applicable. Where Section 4.1(RMI) is not applicable, Ae shall be calculated as:
- where the Q factor shall be determined by the procedure specified in Section 9.2 and Anet min is defined in RMI.
- Lx, Ly and Lt are the unbraced lengths defined in RMI for bending about x- and y axis and twisting. Torsional warping constant Cw may be calculated based on sharp corners.
- Distortional Buckling

- Open sections except those with unstiffened elements or only simple lip edge stiffeners shall be checked for the effects of distortional buckling by testing or rational analysis.
- Hot-Rolled Steel Columns
- All hot-rolled steel columns shall be designed according to AISI (2005) [2] except as noted below. The nominal compressive strength Pn shall be calculated as follows:

$$P_n = A_e F_{cr}$$

- Ae is defined in RMI. The value of Q shall be determined according to RMI. Equations

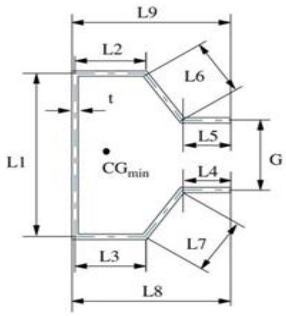
C. Beams

Calculations

The bending moments, reactions, shear forces, and deflections shall be determined by considering the beams as simply supported, or by rational analysis for beams having partial end-fixity. Where the shape of the beam cross section and the end-connection details permit, permissible loads of pallet-carrying beams shall be determined by conventional methods of calculation according to the AISI [1] or the AISC [2].

Cross Section

Where the configuration of the cross section precludes calculation of allowable loads and deflections, the determination shall be made by tests according to RMI Deflections. At working load (excluding impact) the deflections shall not exceed 1/180 of the span measured with respect to the ends of the beam.



	Average dimension
L1	81.14 mm
L2	32.03 mm
L3	31.95 mm
L4	21.56 mm
L5	18.85 mm
L6	24.34 mm
L7	25.36 mm
L8	66.80 mm
L9	67.12 mm
G	41.80 mm
t	2.65 mm
A_{netmin}	478.192 mm^2
CG_{min}	21.605 mm

Fig.4 Cross section of the column

Design concept

The use of thin-walled sections can result in specific design problems due to the failure modes such as local buckling and distortional buckling. The rack sections usually contain holes and imperfections that decrease the resistance of these members. The design rules intended for these members use minimum geometric properties and experimental results to predict the behavior of the structure.

For the evaluation of the load capacity of the column by the RMI specification it is necessary to carry out a stub column compression test of a typical rack cross section. This test uses a specimen that has its dimensions defined in a way to eliminate overall column buckling effects and to minimize the end effects during loading. It is presents a general view of the specimen and its dimensions used in the experimental program.

The specimen is submitted to a compression load applied in the gravity center of the minimum net area of the cross section, CGmin. The load is applied through a Universal Testing

Machine, and transmitted by rigid plates to the column, without any holes in the ends, as shown a schematic view of the stub column test. Through this test the ultimate strength of the column is obtained.

IV INTRODUCTION TO ANSYS

ANSYS is a commercial FEM package having the capabilities ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. It is available in modules. Each module is applicable to specific problem. For examble, Ansys/Flotran is CFD software applicable to Fluid Flow. The advantage of Ansys compared to other competitive software's is, its availability as bundled software of pre, post and a Processor.

Modeling

This is the important step of creating the physical object in the system. They are two types of modeling in Ansys, they are Direct Modeling & Solid Modeling.

a) Direct Modeling

In this approach the physical structure is represented by nodes and elements directly. The problem is solved once after the boundary conditions are applied. This approach is simple and straight forward. Takes very little time computation. But this can be applied only for simple problems. When problem becomes complex, this method becomes tedious to apply.

b) Solid Modeling

Models are directly created either using Ansys preprocessor or imported from popular CAD software's like Mechanical Desktop, Pro/E, CATIA, SOLID WORKS etc. Once the structural model is created, by using mesh tool, the model can be meshed and problem can be solved by applying the boundary conditions.

Specification of the Model
Height of each floor: 2.10 m
Plan dimension:
Single bay length: 2.40 m
Number of bays: 10 Nos
Number of rows: 11.00m
Number of floors: 4 Nos

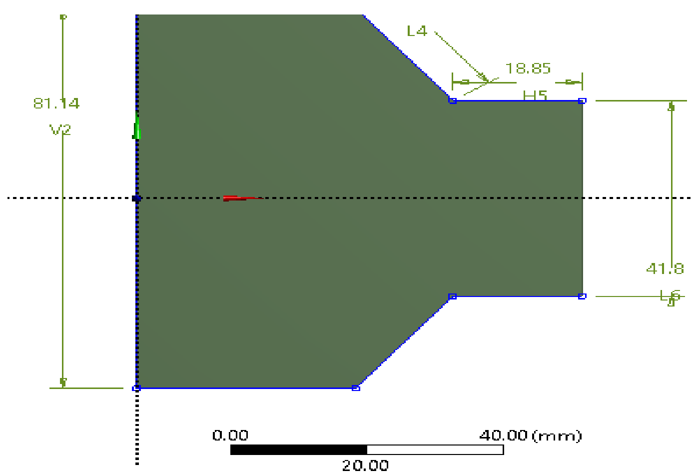


Fig. 5 Cross Section of Column

Corridor width: 1.80 m
Platform width: 1.50 m
Moderate seismic zone: (V)
Live Load: 3660N

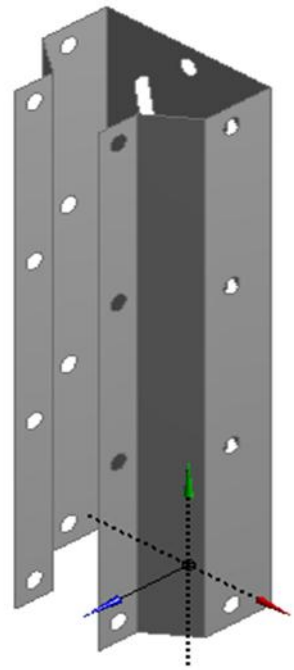


Fig. 6 Side View of Column

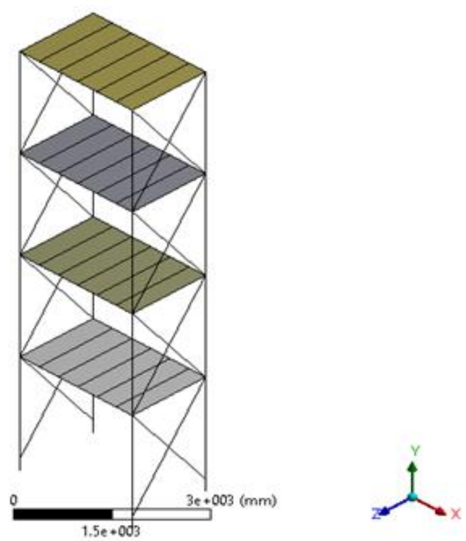


Fig. 7 Model of the End Bay Structure

V RESULTS AND DISCUSSIONS

In this work we analyse the steel storage rack column with different cases. Suck as,

- Normal Column
- Rear Flange Warping
- Flange Warping
- Tempered Self fixing Stiffener

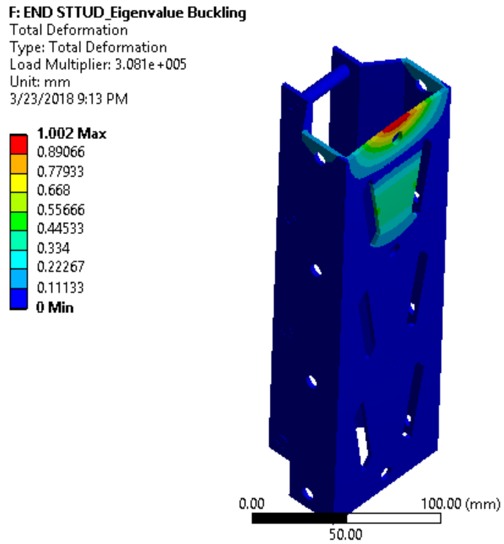


Fig. 8 Result of Rear Flange Warping

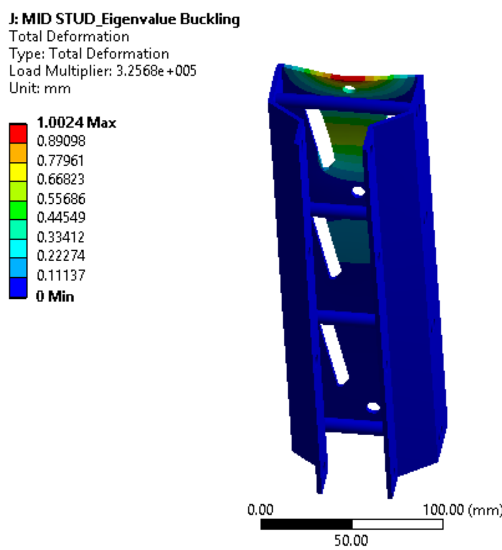


Fig. 9 Result of Flange Warping

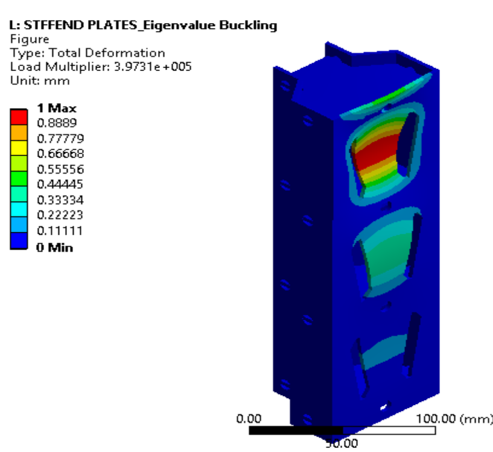


Fig. 10 Result of Tempered Self Fixing Stiffener

These above cases flange warping case has been taken and using this type column we creating the model of End bay, Middle bay. Analysis of these end and Middle bay of Steel storage Column racks.

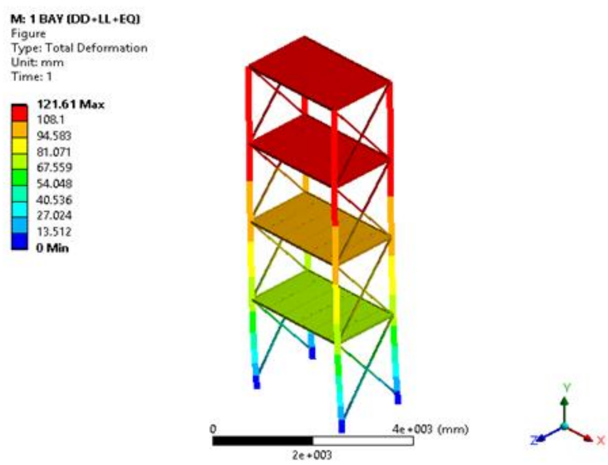


Fig. 11 Result of End Bay Deformation

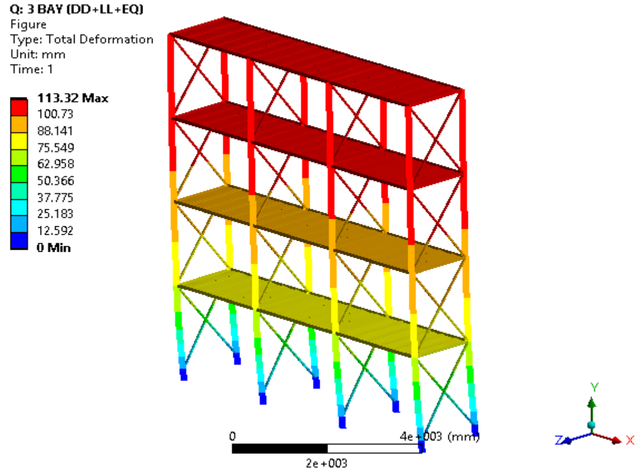


Fig. 11 Result of Mid Bay Deformation

VI CONCLUSION

Hence we concluded that,

1. Flange warping Steel storage rack columns are given good results and to take more load.
2. Steel storage racks with flange warping columns are more moment resistant and total deformation form this type of columns is very less compared to other types of columns.
3. Flange warping Columns are 20% extra Seismic resistant form the other type of Steel storage rack columns.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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