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Research Article

Structural Behaviour of Industrial Pallet Rack with Braced and Unbraced Frames

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Abstract

According to the structural point of view Industrial Pallet rack structure can be considered typical steel framed structure. An analytical study for the sensitivity of pallet rack configuration in linear static equivalent lateral loads is considered for analysis. This work presents a general analysis of an industrial pallet rack structure, evaluating the influence of each of the components on the global stability. The braced/unbraced frames were prepared and analytical models are to be built in software. The FEM is used to determine axial forces in column, maximum storey displacement and story drift on braced/unbraced pallet rack structure. Different types of bracing system are used for study of structural behaviour of an industrial pallet rack steel structure. Bracing systems are mostly provided to enhance the stiffness factor of the structures with the seismic loads. Unbraced systems have been mostly translational modes of failure and are very flexible due to excessive loads

Keywords: *Pallets Rack, Cold Formed Steel, Seismic Design, Finite Element Analysis, Buckling Capacity.*

1. Introduction

Structural analysis programs has been significantly increased the productivity of structural engineers over the past 25 years and have led to more efficient, more innovative, and more economic designs, particularly in the area of steel storage rack structures. Storage racks are built predominantly from cold-formed steel, although when supporting particularly heavy loads, they may be built from hot-rolled steel or tubular sections, which may be hot rolled or cold formed. The main structural members of steel storage rack frames are uprights and pallet beams.

Pallet rack is a material handling storage system designed for the storage of materials on pallets . 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 with metal elements: the fabrication of rack structures constitutes, indeed, an important application of cold formed steel products and steel structures also.

The stability of a structure essentially means the stability of its equilibrium configuration or state. A structure loses its stability due to various external as well as internal disturbances. In a cold-formed structure, instability becomes more prominent due to unsymmetrical and thin section. Stability analysis of an elastic structure mean by the buckling analysis. The main difficulties in cold-formed structural design are local, distortional buckling and warping of section in addition to this behaviour non-uniformity makes the structure more complex for analysis.

Steel rack structures have been widely used in the warehouse industry. They are an effective means of storing goods - strong, light and flexible. A few major and minor collapses of these structures have been reported but a literature review showed that most of the previous work has concentrated on the static behaviour of the structure. Therefore, it is the aim of this research to study the collapse behaviour of rack structures and to propose a solution that is simple and cost effective.

2. Literature Review

Experimental and analytical studies of the seismic performance of storage racks has been scarce and the results often are proprietary; and consequently, they have not significantly influenced the development of codes and regulations related to storage rack systems. This survey paper provides analytical investigations on the seismic response of storage racks are briefly reviewed. Gaps in knowledge requiring further research studies also are identified.

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Murray J. Clarke *et.al* has presented on the global buckling behaviour of high-rise steel storage rack frames. He studied that there is a problem in using the beam elements available in many commercial frame analysis programs which neglect torsional buckling and the coupling between axial, flexural and torsional deformation modes at the element level. It is shown that the mono-symmetric upright columns of a high-rise rack frame fail in a flexural-torsional mode due to the shear-centre eccentricity of the sections, and that the 3D frame buckling analysis is more reliable in determining the critical members of a rack frame.

K.M. Bajoria e*t.al* has presented that the most accurate method of seismic demand prediction on structures is non-linear time history analysis. As an alternative to time history analysis, is the non linear static pushover analysis. The purpose of the push over analysis is to assess the structural performance by estimating the strength and deformation capacities comparing these capacities with the demands at the corresponding performance levels. Model was analyzed using non-linear static pushover analysis. Parameters selected for analysis and design are cross section of uprights, thickness of uprights, and stiffness of the connections. Base shear at the time of collapse is improved step by step either by changing the bracing combination or changing the cross section of upright at points where plastic hinges are forming initially.

Damien Koen studied on the effect of discrete torsional provided by the frame bracing in the cross-aisle direction. The experimental testing of the column frames with K-bracing are been compared to finite elements prediction of displacements and maximum axial loads. Thus FEM is used to determine buckling loads on unbraced and braced column frames of various lengths.

James P. Plantes*et.al* has presented installation guidelines for industrial storage rack; and how a combination of improper installation, maintenance, and operational procedures led to a catastrophic failure of a warehouse storage rack system. The authors demonstrated that current installation guide lines do not provide for adequate stability of storage rack systems and propose that a change from guidelines to prescriptive requirements will provide a safer environment for building occupants and protect against costly property damage and business interruptions due to storage rack collapses.

N. Baldassin*et.al* has studied the behaviour of base-plate connection of steel storage pallet racks under eccentric load is currently in progress. The testing rig and the test procedure have been presented. The level of the axial load applied to the upright, the behaviour of base-plate connection and the interaction between upright and base-plate element play a key role in joint response. Gregory J. Hancock has studied distortional mode of buckling for a rack structure with a cold form steel lipped channel columns including a additional flange stiffening lips which is known as rear flanges. These are used mainly for the bolting of braces to the channel section to the upright frames in rack storage system. analyzing the Theoretical and experimental models for buckling o columns and the result where check from a design chart which included calculation of torsional buckling stresses of various ranges of size of a channel section with rear flanges.

C.Kozkurt*et.al* has studied structural storage of warehouses analyzed with finite element method. Each cell of rack system storages pallet which from 800 kg to 1000 kg weights and0.80x1.15x1.50 m dimensions. Considering this load, total deformations and equivalent stresses of structural elements and principal stresses, tensile stresses and shear stresses of connection elements have been analyzed. Results were evaluated according to resistance limits of structural and connection elements.

N. Baldassino*et.al* design is usually performed adopting 2-D simplified models related to the main frame directions: i.e. down-aisle and cross-aisle direction. The frame stability in down-aisle direction, where usually bracing systems are missing, is ensured by the degree of continuity provided by joints. In the framework of a research work of pallet racks, a research on the response of base-plate joints under axial eccentric load is been under progress

3. Modeling and Analysis

Three models were prepared in the Etabs software for the structural behaviour of cold form steel industrial pallet rack structure. The linear equivalent methods were applied for the seismic forces on both the analysis. First model were prepared using Diagonal braced frames and second were prepared using X braced frames and third were prepared using inverted V braced frames.

Parameters considered for the analysis such as maximum storey displacement and maximum storey drift & axial forces in columns. Dimension for the industrial pallet rack are 10 bays and 5 stories. Each bay with equal spacing 3m apart and story height 1.5m. The mid beams are placed between each bay at centre 0.75m from left. On each bays a steel plate of 10mm is placed and 1.2 tons load is applied on plates as live loads.

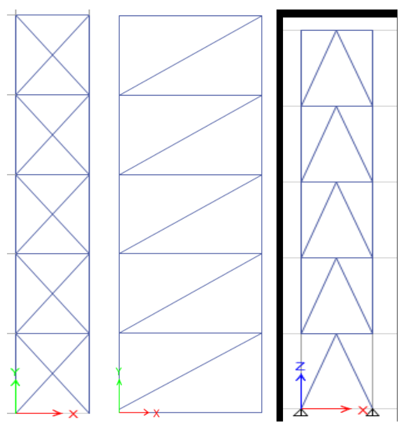

Fig. 1 X- Braced Frame Fig. 2 Diagonal-Braced Frame Fig. 3 Inverted V- Braced Frame

4. Result

The seismic analysis of the frames models that includes diagonal braced frames, X braced frames and inverted V braced frames were done in Etabs software.

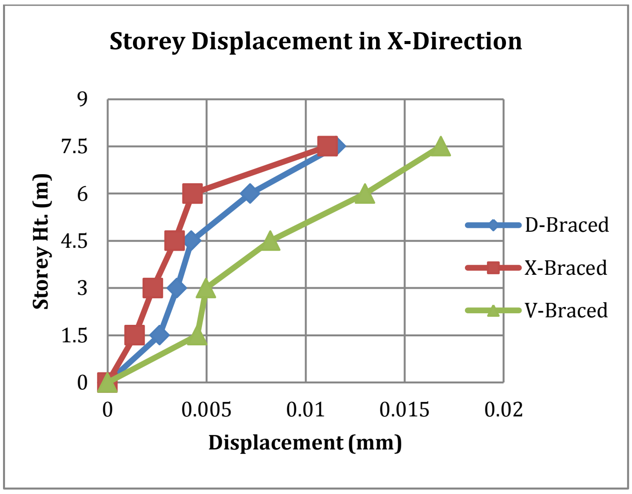

Fig.4 Storey Ht. as a function of Max. Displacement

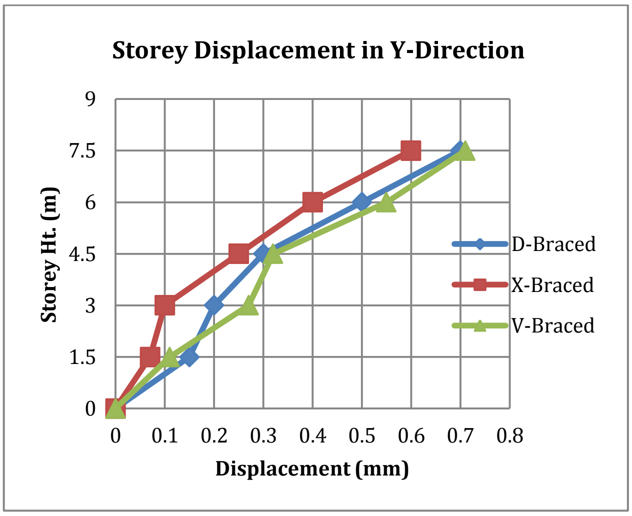

Fig.5 Storey Ht. as a function of Max. Displacement

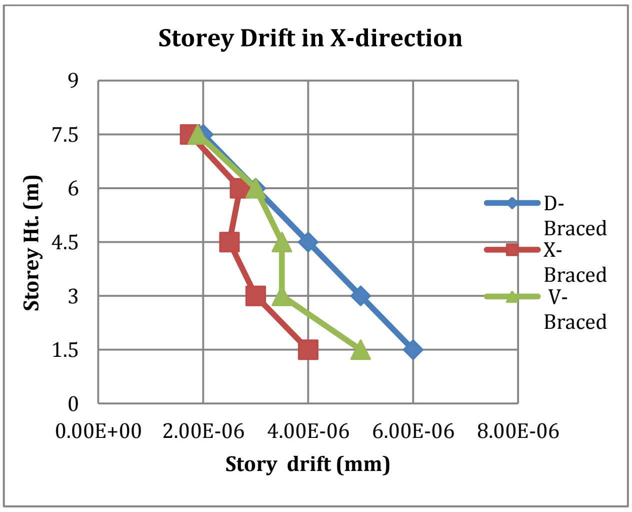

Fig.6 Storey Ht. as a function of Storey Drift

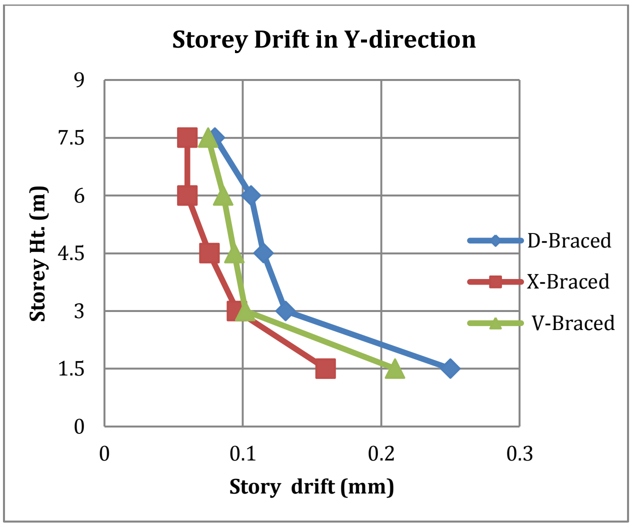

Fig.7 Storey Ht. as a function of Storey Drift

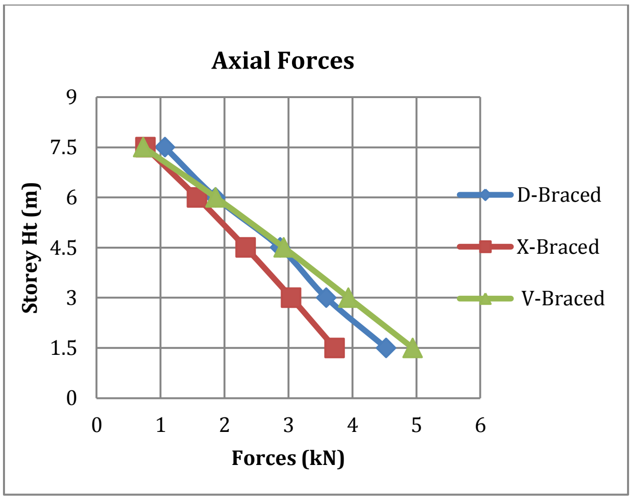

Fig.8 Storey Ht. as a function of Axial Forces

Conclusions

1) Many of the studies have shown structural behaviour of connection of beam and column joints or installation of base plate for the analysis of pallet rack and much less research has been undertaken into more complex sections such as uprights for pallet racking.
2) These studies have led to many advances in cold-formed steel design of industrial pallet rack with different bracings. In proposed work, the forces developed due to seismic action in X direction and Y direction, dead load and live load are considered and the results obtained from the above analysis are to be tabulated, compared.
3) Results on the structural behaviour on the analysis of industrial pallet rack with different braced frames have been studied for various parameters.
4) X braced frames have minimum results compared to Diagonal Braced frame and inverted V braced frames. Therefore X bracing

system is preferred for the industrial pallet rack structure considered with standard load of 1.2tons on each bay.

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