Comparative Study and Cost Evaluation of Combined Pipe Rack and Steel Pipe Rack

Preeti Rathore[1] Prof. D.H.Raval[2]
[1]P.G Student [2]Assistant Professor
[1,2]Department of Applied Mechanics
[1,2]L.D. College of Engineering Ahmedabad, India

Abstract— Pipe racks are essential for the operation of industrial facilities but because pipe racks are considered non-building structures, code referenced documents will usually not cover the design and analysis of the structure. Commonly steel pipe racks are used to facilitate fast and flexible construction; however fire hazard and economy are its prime demerits. Present study aims a comparative study of combined pipe rack made with steel rack and R.C.C support with steel pipe rack which are general in common construction practices. Combined pipe rack is far more advantageous over steel pipe rack regarding structural aspects and construction cost. The result assists to understand a comparative structural behaviour and cost effectiveness of combined pipe rack over steel pipe rack and also can be used as guiding tool for the selection of better system for the pipe racks.

Key words: Combined pipe rack, Steel Pipe Rack, fire hazard, cost effective

I. INTRODUCTION

The pipe rack, as a complete structure system and its structural elements should perform their function adequately and safely, with appropriate degree of reliability during design life. It should withstand all actions, consisting applied and induced loads as well as environmental influences liable to occur, retaining its structural integrity, and also withstand accidental loads and earthquake loads without causing damages[1]. Industry Practices Structural Design Criteria (PIP STC01015) has tried to develop a uniform standard for design but it should be noted that this is not considered a code document.

Commonly steel pipe racks are used to facilitate fast and flexible construction; however fire hazard and economy are its prime demerits. Here the study aims to design a combined pipe rack made with steel rack and R.C.C support which shall combine advantages of steel and concrete (better fire resistant).

A. Advantages of Combined Pipe Rack Over Steel Pipe Rack:

- High strength concrete provides a combination of stiffness and durability that is difficult to obtain with steel. Structurally the greater stiffness of concrete allows it to respond better to accidental & unforeseen loads. Corrosion always an issue with steel, it is much lesser danger with good quality concrete.
- All steel, in specific area of plant and up to specific elevations above grade needs to be fireproofed. Fireproofing has been traditionally done by applying a layer of concrete on steel members. This places an additional burden on the structure, increasing not only its weight but also wind and earthquake forces that the structure needs to resist. Any additional increase in member sizes due to fireproofing ads unproductive steel to the structure and is essentially wastage. Whereas the concrete structure needs no additional fireproofing. All the concrete used in the structure is utilized in supporting the intended loads, actual and anticipated.

II. GENERAL DESIGN APPROACH FOR PIPE RACK

The conventional pipe rack system is essentially comprised of multiple 2-dimensional frame assemblies of two or more columns with transverse beams, which are tied together in the longitudinal direction utilizing beam struts for support of transverse pipe and for longitudinal stability of the system and vertical bracing to form a 3-dimesional space frame arrangement. Main pipe racks are usually designed as moment-resisting frames in the transverse direction. Vertical bracing in the longitudinal direction are provided to transfer the longitudinal forces through the beam struts, to the foundation system [2]. Transverse beams designed to resist all forces and moments under the stipulated load combinations. Transverse beams are analysed and designed as moment-resisting frame with MRC connections between the columns and the beams.

The allowable deflections of pipe rack structures are set by the criteria set in each project design. However, for pipe racks supporting piping only excluding equipments the limit is h/200 or as per accepted criteria and the same is reduced to h/100 for pipe racks supporting equipment, where h is the total height of the pipe rack structure [3]

III. DESIGN PHILOSOPHY

This block of pipe rack is 40.0m long and designed as an independent model. Width of pipe rack is 6m and spacing between transverse frames is 6m from grid 3 to 7 and 8m in grid 1-2. The pipe rack comprises of cast-in-situ rigid main frames in transverse direction and longitudinal direction. The pipe rack is modelled as 3D space frame and all columns, main beams, longitudinal beams, cable tray supporting secondary beams are modelled in STAAD pro V8i. The piping blanket loading of 1.5 kN/sqm in erection condition and 2.0 KN/sqm in operating condition is considered. The Plant is located at Petrochemical Complex at Panipat, Hariyana, which lies in Seismic Zone VI Earthquake / Seismic analysis on the piperack has been performed as per IS:1893 Part I & 4. Wind load on piperack has been calculated as per IS:875 (Part 3) - 1987.

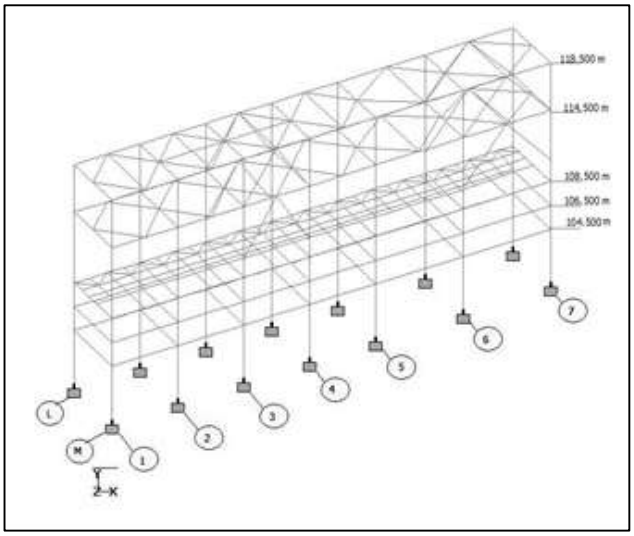

Fig. 1: 3-D model of combined pipe rack

- Pipe racks are usually designed with special moment resisting frames (SMRF) in the stronger direction to allow operational facility and maintenance equipment access, and the placement of main piping.
- The weak structural directions, on the other hand, are usually designed with braced frames due to stiffness concerns and less access requirements. The braced frames are effective structural forms for providing stiffness.
- Vertical and plan bracings are provided as double angle and are define as truss members in STAAD Pro.
- Anchor forces are applied at bay number 3rd and 6th as it is define as anchor bay, and usual practice is that anchor bay should be braced but as most of the piping is coming in at same bay so bracings in longitudinal direction is provided at the same bays.

IV. MODELLING AND MEMBER DEFINITION

Figure 2 below represents the geometrical configuration for combined pipe rack in longitudinal direction with respective section properties.

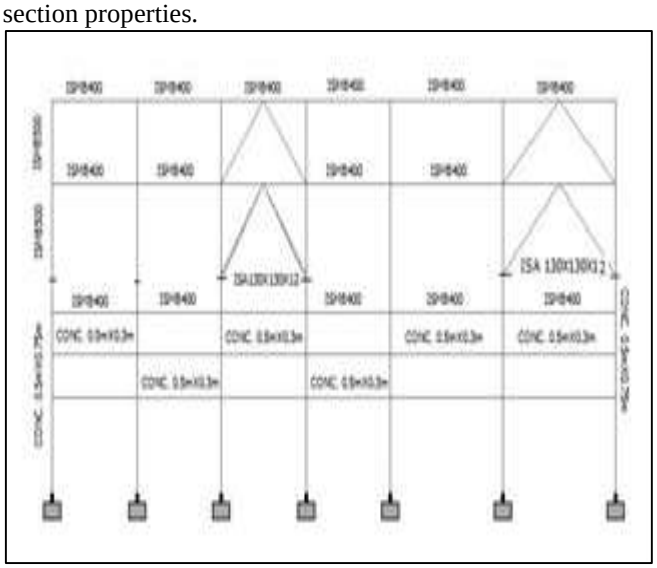

Fig. 2: Longitudinal direction of combined pipe-rack

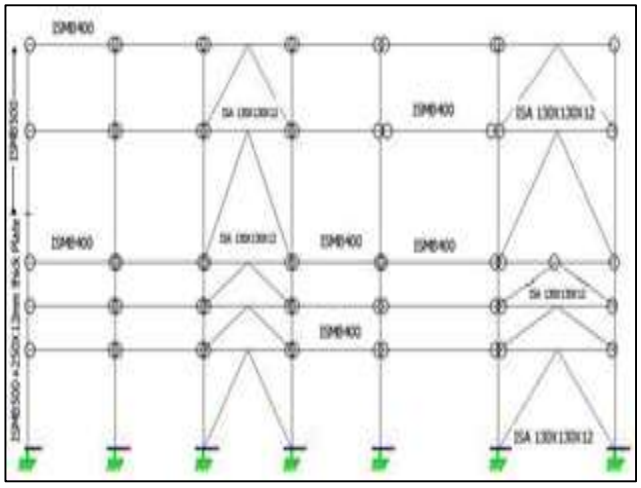

Fig. 3: Longitudinal direction of steel pipe-rack

For comparative study the steel pipe rack was modelled under same geometrical configuration and loading as done in combined pipe rack. In combined pipe rack till height 10.0m RCC column and beams were designed for better fire safety and rest of the height was designed as steel sections for both columns and beams whereas in Steel pipe rack, the overall structure is designed as steel sections as shown in fig 3. A comparative analyzation is done for both pipe racks.

V. LOADS

Dead load accounts for self-weight of the structure, walkways, cable tray and grating. Live load comprised of conveyance pipes of two different diameter pipe both were greater than 12". Load for pipe erection, pipe operation and pipe testing were considered as 1.5kN/m, 2kN/m and 2kN/m respectively. Seismic loads were calculated as per IS 1893(Part I and IV), 2002. As pipe rack comes under non-building structure, the structure type was taken as 2 and reduction factor R was considered as 4 [6].

VI. .COMPARATIVE STUDY

Analysis of combined pipe rack and steel pipe rack are done and results are as follows

Factors	Combined Pipe Rack	Steel Pipe Rack
Time Period (sec)	0.547	0.816
Top nodal displacement (mm)	48.086	54.09
Storey drift (mm)	2.34	3.41
Base Shear (kN) (x-direction)	793.68	542.42

Table 1: showing comparison of combined pipe rack and steel pipe rack

Through STAAD, values of the time period for both structures are extracted .The maximum time period is of steel pipe rack, it means it is more flexible to oscillate back and forth when lateral forces act on it. Also results show that combined pipe rack has less time period which says it is very less flexible then the steel pipe rack.

From table 1, the maximum nodal displacement is shown by Steel pipe rack than in combined pipe. This is because; steel pipe rack is more flexible as compared to combined pipe rack.

Property	Combined Pipe Rack	Steel Pipe Rack
Max. Axial Force (kN)	1476.92	1298.67
Max. shear Force (kN)	220.334	192.89
Max.Bending moment(kN.m)	567.033	512.93

Table 2: showing Comparison of various parameters

There is increase of about 10% in axial force and moments in transverse and longitudinal direction of combined pipe rack then in steel pipe rack. Combined pipe rack also shows increment of 15% in shear force as compared to steel pipe rack

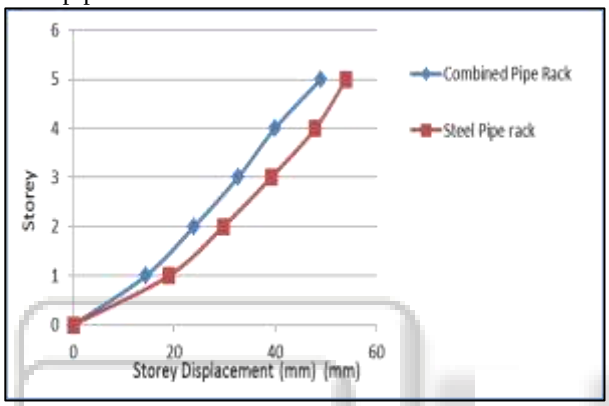

Fig. 4: Showing Comparative Storey Displacement for Combined And Steel Pipe Rack

From the fig.4 it is observed that the displacement for combined pipe rack is less as comparative to steel pipe rack, this is due to more flexibility in steel pipe rack as compare to combined pipe rack. There is a increase of about 20% in storey displacement for steel pipe rack then in combined pipe rack.

VII. Cost comparison

The cost comparison between combined pipe rack and steel pipe rack is represented by following bar chart.

The study shows that cost of manufacturing of a combined pipe rack is about 23 lakh (INR) as compared to 42 lakhs (INR) cost of manufacturing of steel pipe racks, which is almost 1.8 times the combined pipe rack.

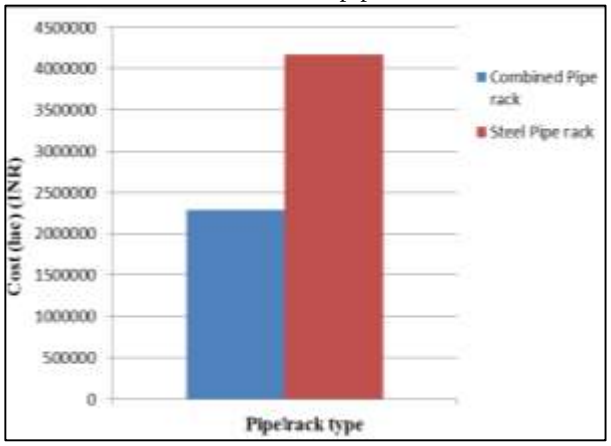

Fig. 5: bar chart showing cost comparison for combined pipe rack with steel pipe rack

VIII. Conclusion

1) From the various analysis carried out it is observed that, Base shear in steel pipe rack is less than the combined pipe rack because of less seismic weight which gives better response during earthquake.
2) It is clear that the nodal displacements in a combined pipe rack compared to steel pipe rack in all the three global directions are less which is due to the higher stiffness of members in a combined pipe rack as compared to steel pipe rack.
3) As concrete gives better fire protection, so combined pipe rack will be more suitable than steel pipe rack but the construction time is more in combined pipe rack as compared to steel pipe rack. Speedy construction facilitates quicker benefit in terms of rent and time.
4) From the analysis it can be seen that steel pipe rack is more flexible than to the combined pipe rack and more flexibility could lead to the serious damages in petrochemical station.
5) As concrete gives better fire protection, sometimes steel sections are embedded in concrete to get this advantage and so the cost of steel pipe rack still increases
6) Combined pipe rack are very cost effective than the steel pipe racks. Percentage saving in cost achieved is about 45%.
7) Though steel pipe racks are very costly, but they are better for fast construction and so when time of construction is constraint, then steel pipe rack is better option.
8) As concrete gives better fire protection, so combined pipe rack will be more suitable than steel pipe rack.

References

[1] Mohammad Karimi.," Seismic Evaluation of Pipe Rack Supporting Structure in a Petrochemical Complex in Iran". International Journal of Advanced Structural Engineering, 2011
[2] American Committee 318, "Building Code Requirement for Structural Concrete and Commentary (ACI318-02)", American Concrete Institute, Farmington Hills, MI, USA.,1997.
[3] American Society of Civil Engineers," Guidelines for Seismic Evaluation and Design of Petrochemical Facilities", ASCE, New York, NY., USA.,1998.
[4] Drake, Richard M. and Walter, Robert J., "Seismic Design of Structural Steel Pipe Racks". Structure Magazine, 2012.
[5] J. G. (Greg) Soules,"Non-Building Structure Design".
[6] ASCE Standard 7-05," Minimum Design Loads for Building and Other Structures", USA.
[7] IS: 1893-2002, Indian Standard Criteria for Earthquake Resistant Design of Structure.

