

Comparative Study of Steel and Combined (Steel and RCC) Piperack Considering General and Emergency Load Cases

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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 utilization ratios are less in case of combined Piperack than the steel Piperack for general and emergency cases. The story drift and top nodal displacement are less in case of combined Piperack than the steel Piperack for general and emergency cases, this is due to high stiffness of members in the combined Piperack than the steel Piperack. The max displacements are less in case of combined Piperack than the steel Piperack for general and emergency cases as the steel Piperack is more flexible than the combined Piperack. In Emergency case condition the steel Piperack is poor since it has steel column at base which is having chances of damage to the column in the form of failure of column, local bending or buckle due to vehicular impact load. In Emergency case condition two the combined Piperack is better since it has RCC rigid column at base which is resist the vehicular impact loads and avoid damage to the column. The Combined Piperack is provide strength and serviceability through its life period as compared to steel Piperack even in case of emergency cases as the RCC columns resist the impact of vehicle (Fire truck) also it has good fire resistance than steel. From the analysis and results it is seen that the combined Piperack are more rigid and steel Piperack are flexible this could be leads to serious damage in Oil and gas facility. As concrete give better fire protection than the steel the combined Piperack will be more suitable than the steel Piperack. As concrete is more fire resistance than steel it is more suitable the construction time will be more than in case of steel Piperack. Though the steel Piperack's are costly it takes less time for erection and construction quality can be achieved hence when there is time constrain the steel Piperack is better option. The steel tonnage require in case of combined Piperack is less than in case of steel Piperack about 18.79% steel qty is saved in case of combined Piperack.

KEYWORDS: Industrial Building, Cost Difference, Axial Force, Node Displacement, Max Bending Moment and shear Force, Steel , RCC, Piperack

1. INTRODUCTION

1.1 Background of research work

Pipe networks are considered as main components of industrial complexes like refineries and petrochemicals that transfer fluid and gas.[2]Piperack is concrete or steel structure which carries multiple pipes carrying liquid or gas in different tiers and carries Electrical/Instrument/Telecom Cable trays and supports auxiliary Equipment etc. with service platforms and walkways.



Figure 1: Piperack structure

1.2 Piperack structure

Piperack is the main artery of a process unit. It connects all equipment with lines that cannot run through adjacent areas. Because it is in the middle of the most plants, the Piperack must be erected first, before it becomes obstructed by rows of equipment. Piperack carry process, utility piping and include instrument and electrical cable trays as well as equipment mounted over all of these. Fig. 1 shows a typical Piperack. The primary data required for detailed development of a Piperack: -

1. Plot Plan
2. P&ID's
3. Client Specification
4. Construction Materials
5. Fire proofing requirements
6. Statutory requirements

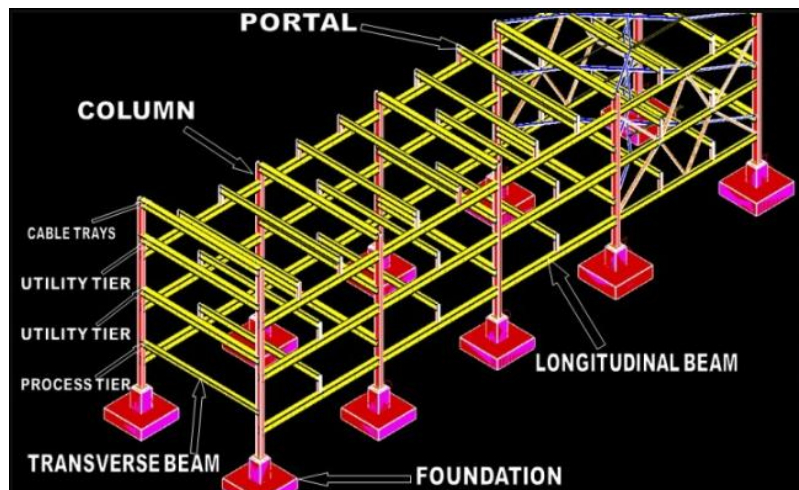


Figure 2: Piperack general arrangement

1.3 Piperack Design criteria

- **Shapes**

There are various shapes of Piperack like L/T/U/H/Z. These shapes shall be considered based on the area available.

- **Future Space**

The total width of the Piperack shall include 25% extra space for future expansion/modification in unit for rack-width up to 16 m and 10% for rack-width above 16 m. The future space %age is normally based on the client requirements.

- **Width of Piperack**

The width of the rack shall be 6 m, 8 m or 10 m for single bay and 12 m, 16 m or 20 m for double bay having 4 tiers maximum. The spacing between Piperack portals shall be taken as 6m in general. However, it can be increased to 8m depending on the size of the pumps to be housed below Piperack. Calculate the width of Piperack

- **Clearance**
For units, clearance beneath Piperack shall be 4 m minimum both in longitudinal and transverse directions.
- **Position of Lines:** Predominantly process lines are to be kept at lower tier and, utility & hot process lines on upper tier.
- **Hot Lines & Cold Lines:** Generally hot lines & cold lines are to be kept at different tiers or at different groups on a tier.
- **Pipe Spacing:** Minimum spacing between adjacent lines shall be decided based on O.D. (Outer diameter) of bigger size flange (minimum rating 300# to be considered), O.D. of the smaller pipe, individual insulation thickness and additional 25mm clearance. This shall be decided by the Piping/Mechanical department.
- **Anchor Bay:** Anchor bay is the fixed bay where pipes are restrained/ fixed in all direction. Anchors on the racks are to be provided on the anchor bay if the concept of anchor bay is adopted. Otherwise anchor shall be distributed over two to three consecutive bays.
- **Pipe Route:** Racks shall be designed to give the piping shortest possible run and to provide clear head rooms over main walkways, secondary walkways and platforms.
- **Cable Trays:** Generally top tier is to be kept for Electrical cable trays (if not provided in underground trench) and Instrument cable ducts/trays. Cable tray lying to take care of necessary clearances for the fire proofing of structure.

1.4 Basic pipe supports

Pipe load for Piperack loads shall be given by Mechanical stress group to Civil & structural discipline for Piperack design. The Piperack structure consists of various floors called as tiers on which pipes are running. These pipes are supported by primary support (Given by Piping/Mechanical department) followed by steel beams which are further supported by steel or RCC column. The basic primary support may consist of following;

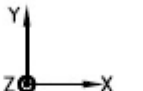
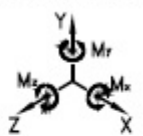




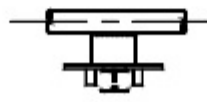

SUPPORT CLASSIFICATION (FUNCTIONS)	BASIC CONSTRUCTION	* SYMBOL	RESTRAINTS
			
LOOSE SUPPORT			(+) Y
LONGITUDINAL GUIDE			(±) Y & (±) X
TRANSVERSE GUIDE			(+) Y & (±) X

Figure 3: Basic primary pipe supports

The rest supports will transfer only gravity loads in the rack as its purpose is to just rest the pipe on the rack. Guide support may be two-way guide or four-way guides, generally in the piper rack system two-way guide support is provided. The purpose of this support is to transfer the vertical and lateral load. Similar the anchor support is the support which generally provides restraint in three directions. These are critical supports in the Piperack which generally needs a special provision to resist this axis and lateral forces by means of anchor bay.

The pipes are of varying size. Generally, for the Piperack system the pipe size less than 12 inch is consider as noncritical and pipe size which are greater than 12 Inches are considered as critical as it needs special analysis from Piping/Mechanical department. The loads for these pipes are analyses by using CEASER software and loads will be given as input for structural analysis and design.

For present thesis we have considered Piperack structure in the ongoing petrochemical project at Russia for our study.

1.5 Aim

To develop mathematical model for steel and combined (i.e. Steel and Concrete) Piperack to analyze, design and study structural behavior and cost comparison under general and emergency cases by using STAADCONNECT Edition.

1.6 Objectives

1. To develop mathematical model for analysis and design of steel and combined (i.e. Steel and Concrete) Piperack by using STAADCONNECT Edition.
2. To analyze and design Piperack structure for general load cases and emergency load cases.
3. To study structural behavior of steel and combined Piperack by comparing various parameters for general and emergency load cases.
4. To study cost comparison of steel and combined Piperack for general load case design.
5. To study cost comparison of steel and combined Piperack for emergency load case design.

1.7 Scope of research work

For this research the Piperack structure is taken from ongoing project at Russia and analysis and design is done as per Indian standard. The structure has been analyzed by using STAAD CONNECT Edition software and results and finding are explained. For analysis and design various loads are to be taken from Indian standards and Process industrial practices (PIP) standards wherever applicable. The scope is limited to study for comparison of steel and RCC Piperack from cost effectiveness point of view, structural behavior point of view and its performance in the general and emergency cases.

1.8 Significance of research work

The work to be carried out will cover the study of performance of steel and combined Piperack by comparing various parameters, Cost effectiveness by comparison of steel and combined Piperack design under general and Emergency load situations. This will help to find out the optimum design type of Piperack. The structural behavior of steel and RCC Piperack under various emergency cases occurred in the Piperack system. This will help to suggest the type of Piperack to behave well under emergency cases also which should be cost effective and providing good service thought its life span.

II. LITERATURE SURVEY

2.1 Introduction

In this chapter a review of literature related to Piperack system design for steel and combined Piperack is mentioned. A review of published work on comparative and optimized design of Piperack structure and their results are presented. Various literatures have presented in the form of technical papers till date. Some of those are discussed below:

2.2 General for Piperack design

Richard Drake & Robert Walter (2014) Engineering Journal (AISC), 4th Quarter, 2011. ,Piperack are not only Non-building structures that have similarities to structural steel buildings but also have additional loads and design considerations. The requirement found in the building codes apply and dictate some of the design requirement. Some code requirement is not clear on how they are to be applied to Piperack, because most are written for buildings. Several industry references exist to help the designer apply the intent of the code and follow expected engineering practices. Additional and updated design guides are needed so that consistent design methods are used throughout the industry.

Akbar Shahiditabar & Seyed Rasoul Mirghaderi, Pipe and Piperack Interaction International Journal of Applied Science and Vol. 3 No. 5; May 2013. conclude that, a new method for considering pipe and Piperack interaction instead of current method to solve current problems. In the proposed method, pipe is framed to Piperack in all points and then pipe and supporting structure are design simultaneously. The proposed method is assessed by modeling in SAP and CEASER programs with nonlinear static analysis which results confirm our claims. In suggested method, current problems are solved, and the amount of used materials is reduced up to 29%.

David A. Nelson, Walla University, concluded that, For the representative Piperack model, both pinned and fixed base conditions, the first order, effective length, and direct analysis methods were all found to be valid methods of stability analysis according to AISC 36010. All methods give comparable results. Several observations on each method

can be made based on the analysis and results. The direct analysis method provides the most accurate results since reduction in stiffness is considered in analysis. There are also many benefits in application of this method with the most significant benefit being that the effective length factor K can be set to 1 for all cases. This can significantly simplify calculations required to perform analysis especially for moment frames

The first order analysis is a mathematically simplified analysis method. The greatest benefit as the name implies, is that the method only requires a first order analysis. As with the direct analysis method, K can also be set at 1 for all cases. Based on the above simplifications, analysis can be significantly simplified. The effective length method is probably the most well-known method for stability analysis. However, as the name implies, the effective length factor K must be calculated. Based on the discussions in previous sections, this can become very complex even for relatively simple structures

2.3 Optimization inPiperack design

Preeti Rathore & Prof. D.H.Raval, (IJSRD, Vol.4 No.3, 2016),conclude that,Base Shear in steel Piperack is less than the combined Piperack because of less seismic weight which gives better response during earthquake. As concrete gives better fire protection, so combined Piperack will be more suitable than steel Piperack but the construction time is more in combined Piperack as compared to steel Piperack. Speedy construction facilitates quicker benefit in terms of rent and time. Though steel Piperack are very costly, but they are better for fast construction and so when time of construction is constraint, then steel Piperack is better option. SteelPiperack is more flexible than to the combined Piperack and more flexibility could lead to the serious damages in petrochemical station. In this research comparative study for steel and combined Piperack for parameters like displacement, base shear and time periods has been done and results were discussed. But in this research emergency cases were not considered.

M.G.Kawade& Prof. A.V.Navale, (IJRESM, Vol.2 No.2, 2019), ThePiperack are very complex and long structures. The real common problem in industry is taken and an attempt is made for optimization by changing the position and pattern of bracing. Three cases were considered for study. In this, first case is Piperack with bracings are provided at 6th bay from either side, second is Piperack with bracings at center and third is Piperack same as case I with split at center. The use of software STAAD-Pro is done for analysis and design. IS 800:2007 along with other relevant codes is used. It is observed that the most optimized design is obtained when bracing is provided at the center. Steel quantity for Piperack with bracing at center is economical than Piperack with bracing at two sides and Piperack same as case but split at center. The structural arrangement in case two i.e. Piperack with bracings at center is optimum solution.

In this research the conclusions are, Vertical deflection of structural members is less in case two i.e. Piperack with bracing at center than case one i.e. Piperack with bracings at 6th bay from either side and case three i.e. Piperack same as case one but split at center. Steel quantity for case one i.e. Piperack with bracings are provided at 6 m from either side is 102.01 tones, for case two i.e. Piperack with bracings at center is 97.96 tones and for case three i.e. Piperack same as case one with split at center is 101.58 tones i.e. steel required is more by 5% and 4% in case one and case three respectively, as compared to case two.

Nitesh J. Singh & Prof. Mohammad Ishtiyaque, (eISSN: 2319-1163 | pISSN: 2321-7308), In this thesis they have tried to design the Steel Piperack as per International standards which has been accepted most part of the world. Transverse direction is considered as Moment frame and Longitudinal as Shear connection to tackle the loading as per piping stress analysis. Plan bracing is provided in top and bottom tier so that lateral deflection can be optimized and distributed to the Anchor bay location. Anchor bay is provided in every Steel structure at maximum interval of. Vertical bracing is provided up to top tier on both Transverse and longitudinal direction so that all the lateral forces get transferred through this vertical bracing to the base. Fireproofing criteria has been also considered as per International standard to tackle fire hazard. The Structure has been designed in two parts as Strength design and Serviceability design for proper analysis and design of structure. Base Plate and Pedestal has been designed as per AISC codes considering support reactions. Then the Footing is designed in Staad Foundation by importing Staad model to get optimized footing design.

In this research the conclusions are, through this thesis they tried to maximize the distance between supports keeping the value of stresses and deflection within safe limit. Supporting beams are spaced at 6m c/c to support pipe larger than 12' dia. So that no. of continuous beam member is reduced on larger scale. The aim is to reduce the number of supports to reduce the total cost of erection. Plan bracings are provided in K & L shape to resist lateral deflection and transfer the lateral load through vertical bracings.

2.4 Emergency cases in Oil and gas industry

Industrial facility and earthquake engineering by Mohamed Dalli, It is evident that the industry standards are still lacking the consistency needed in terms of design approaches and the philosophy behind it. While this paper has a limited coverage of the issues and topics found in the design of industrial buildings and structures, it is nonetheless hoped that the idea of a need of consolidated building code for industrial buildings is conveyed. A strong interaction and coordination between the structural engineers and the other discipline engineers such as process, electrical, mechanical and piping is clearly and fundamentally very important in delivering a project that has a consistent approach in terms of earthquake design, i.e., the performance level desired by their owner is achieved in its entirety rather than by each discipline operating in isolation. A clear and simplified consolidated building code for industrial structures, will avoid all the confusions encountered in the present building codes.

Chemical release caused by natural hazard events and disaster by World Health Organization, A Natch event is a technological accident triggered by a natural hazard. These can include floods, earthquakes, lightning, cyclones and extreme temperatures (10, 11). A technological accident can include damage to, and release of chemicals from, fixed chemical installations, oil and gas pipelines, storage sites, transportation links, waste sites and mines. The frequency of such events is not well known, but an analysis of a number of chemical accident databases found that 2–5% of incidents resulting in the release of hazardous substances were triggered by natural hazard events, and these figures were considered to be underestimates due to the underreporting of low consequence accidents. It is likely that impact of Natch events is increasing, due to a combination of increasing industrialization and urbanization coupled with a predicted increase in hydro meteorological hazards caused by climate change.

LPG fire at Valerio-Mc Kee refinery U.S. Chemical safety and hazard investigation board, “fire resistant insulating material applied to steel to minimize the effects of fire exposure by flame impingement, to reduce the steel’s rate of temperature rise, and to delay structural failure” (API Publication 2510A, 1996). Without fireproofing, exposed structural steel members, such as Piperack support columns, can rapidly lose their strength and fail, possibly within minutes (API 2218, 1999; CCPS, 2003). Jet fires, such as the pressurized LPG release in this incident, can cause very rapid heating and failure of unprotected structural steel (Appendix E). Fireproofing is a passive defence that can maintain the integrity of protected structures until a fire is controlled.

Ministry of construction and housing and communal services Russian federation, (No-1105 / pr, August 3, 2017). Describes general requirements for accounting emergency design situations. The supporting and enclosing structures of buildings and structures must be designed considering justified emergency design situations that are set by the customer in the design assignment.

2.5 Need of present investigations

Reviewing the past investigations, it is revealed that the Piperack is designed as steel or combined by considering the loads. steel Piperack is time saving as it is easy to erect and construct also construction and erection cost can be saved. Combined Piperack is having good performance as it is having higher stiffness than that of steel Piperack.

III. METHODOLOGY

3.1 Introduction

To achieve the objectives, methodology has been set up. In the methodology two mathematical models are created,

Model 1- Steel Piperack.

Model 2- Combined Piperack (RCC and Steel).

These models are created and analyzed by using STAAD CONNECT Edition software. Following is the detailed methodology described to achieve the objectives.

3.2 Geometry and modeling

To achieve the objectives and results two mathematical models are created by using STAAD CONNECT Edition. Length of the both Piperack model is kept same 49 m and consist of 8 no of grids spaced 7m c/c for both the models. The Piperack consist of total 6 tiers out of which five will be pipe supporting and top will be considered as for cable tray support. The tier consists of levels as EL+10.4 (Tier-1), EL+13.8 (Tier-2), EL+18.2 (Tier-3), EL+21.8 (Tier-4), EL+25.6 (Tier -5), EL+28.6m (Tier-6), The top cable tray supporting tier is protected with roofing and side cladding to protect from rain. The Piperack also consists of the walkway for inspection purpose.

Anchor bay is considered at middle bay defined by the piping/mechanical department i.e. at same distance from both end columns. The access way is provided through the Piperack for movement of fire trucks.

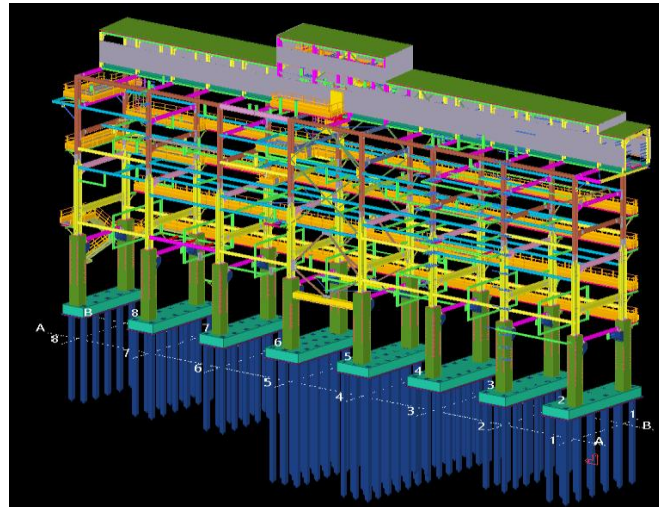


Figure 4: 3D Model of Piperack

3.2.1 Description of geometry

3.2.1.1 Model 1 –

- Structure comprises of RCC column up to EL +11.000 m & Steel structures from EL +11.00 m to +35.00 m (Row A to B & Axis 1 to 8).
- Structure consists of 1 bay 6.000 m span in transverse direction (E-W) & 7 bays of 7.000 m span in longitudinal direction (N-S).
- H.P.P elevation is EL +5.00 m which is 208.500 BSL.
- This structure is 6.000 m wide in E-W direction and 49.000 m long in N-S direction.

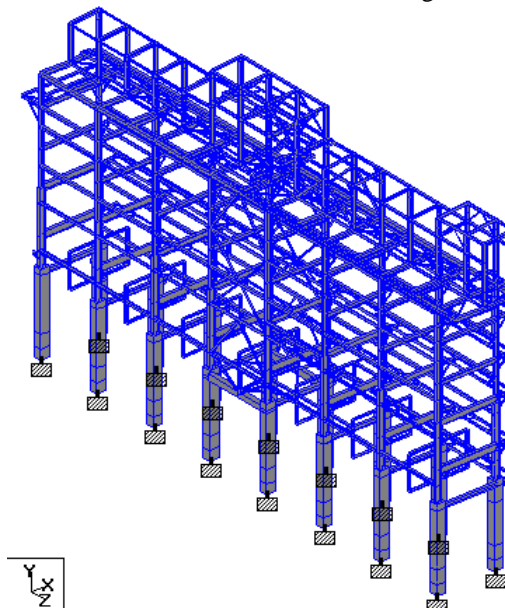


Figure 5: 3D Staad Model of combined Piperack (Model 1)

3.2.1.2 Model 2 –

- Structure comprises of RCC pedestal up to EL +5.300 m & Steel structures from EL +5.300 m to +35.00 m (Row A to B & Axis 1 to 8).

- Structure consists of 1 bay 6.000 m span in transverse direction (E-W) & 7 bays of 7.000 m span in longitudinal direction (N-S).
- H.P.P elevation is EL +5.00 m which is 208.500 BSL.
- This structure is 6.000 m wide in E-W direction and 49.000 m long in N-S direction.
- The structure is braced in N-S direction and moment frames are along E-W direction.

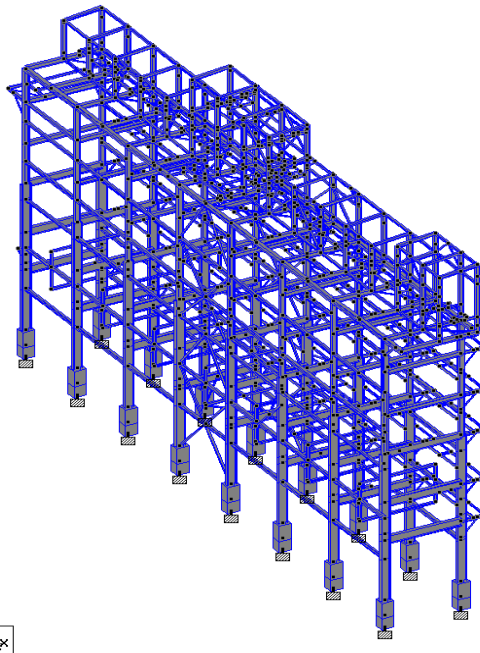


Figure 6: 3D Staad Model of Steel Piperack (Model 2)

3.2.2 Design criteria

- Three-dimensional mathematical model is analysed by using STAAD.CONNECT Edition.
- Steel columns are considered as pinned at base plate level for model 1 and model 2.
- All RCC Pedestals have fixed support about both X & Z direction at bottom of foundation for both the model.
- Loads in various load cases are considered as per Russian standards, Indian standards, PIP standards and for some load cases it is considered from reference drawings.
- Piperack is analysed considering Moment frame in Transverse direction (E-W) & Braced frame in Longitudinal direction (N-S).
- Lateral Deflections check is carried out from nodal displacements.
- Responsibility level considered for the structure is high.
- Reliability factor of 1.1 is considered for steel design.

3.2.3 Computerized analysis criteria

- STAAD. CONNECT Edition software has been used for the analysis purpose. 3D model of structure up to bottom of foundation with framed beams & columns have been prepared for space frame analysis in STAAD.
- 3D analysis model considers nodes at centre line of columns and beams for simplicity.
- All other assumptions have been mentioned as and where applicable.

3.2.4 Computer model

The structure is analysed by computer program. The general system of the computer model is with global axis system: The details are shown for Model one only,

- X = Horizontal axis in computer model along West -East direction.
- Y = Vertical axis in computer model (positive upward direction)
- Z = Horizontal axis in computer model along North - South direction.

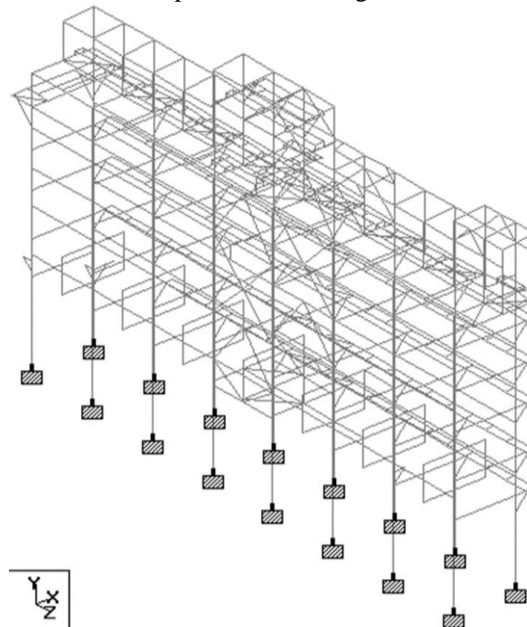


Figure 7: Staad Model of Combined Piperack (Model 1)

IV. VALIDATION

4.1 Problem statement

Validation of Manual Vs Staad analysis results

Given data: Simple freestanding RCC member is considered with 3m height and 1m width and 1m depth and at each 1 m height 10kN load is applied.

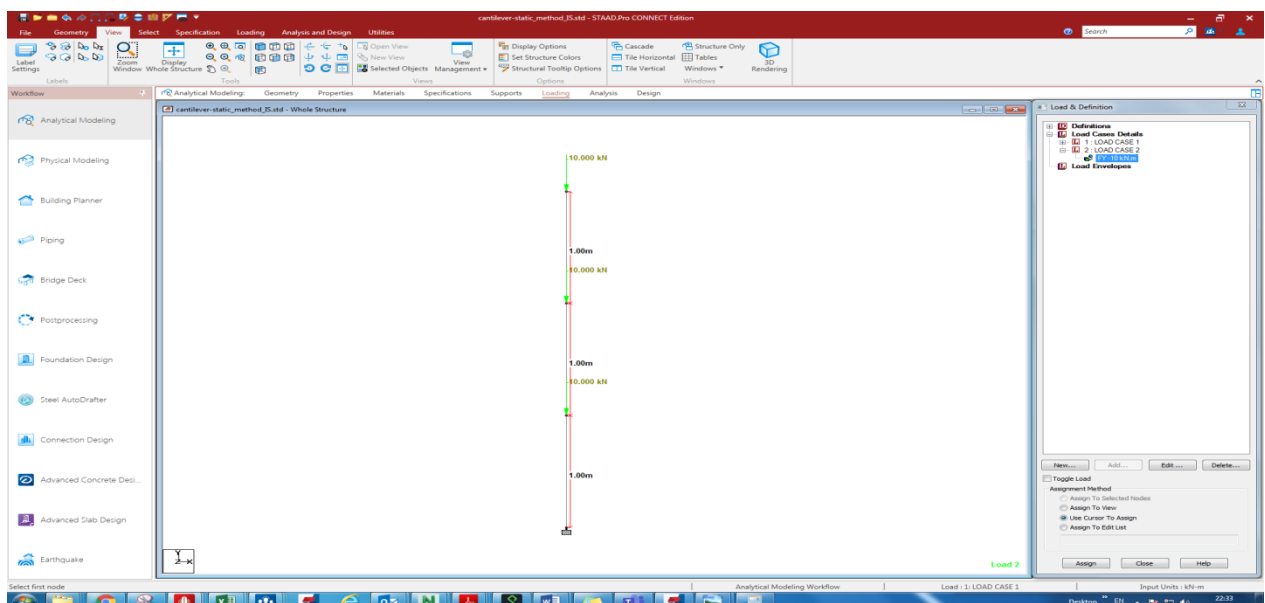


Figure 8: Staad Validation Problem Geometry and loading



Soil Condition: Hard Murom
 Zone-III
 Importance factor -I

Solution:

Total seismic weight = 10 + 10 + 10 = 30kN

Natural period along X direction

$$T_a = 0.075 h^{0.75} = 0.075 * 3^{(0.75)} = 0.1709 \text{ sec.}$$

Design horizontal acceleration coefficient X direction

$$A_h = \frac{Z I S_a}{2 R g} = 0.16/2 * 1/4 * 2.5 = 0.05$$

Design base shear along X direction

$$V_B = A_h * \sum W = 0.05 * 30 = 1.5 \text{ kN}$$

Staad Result

```
*****
* UNITS - KN   METE                               *
* TIME PERIOD FOR X 1893 LOADING =   0.17096 SEC  *
* SA/G PER 1893=    2.500, LOAD FACTOR= 1.000   *
* VB PER 1893=    0.0500 X    30.00=    1.50 KN  *
*                                                    *
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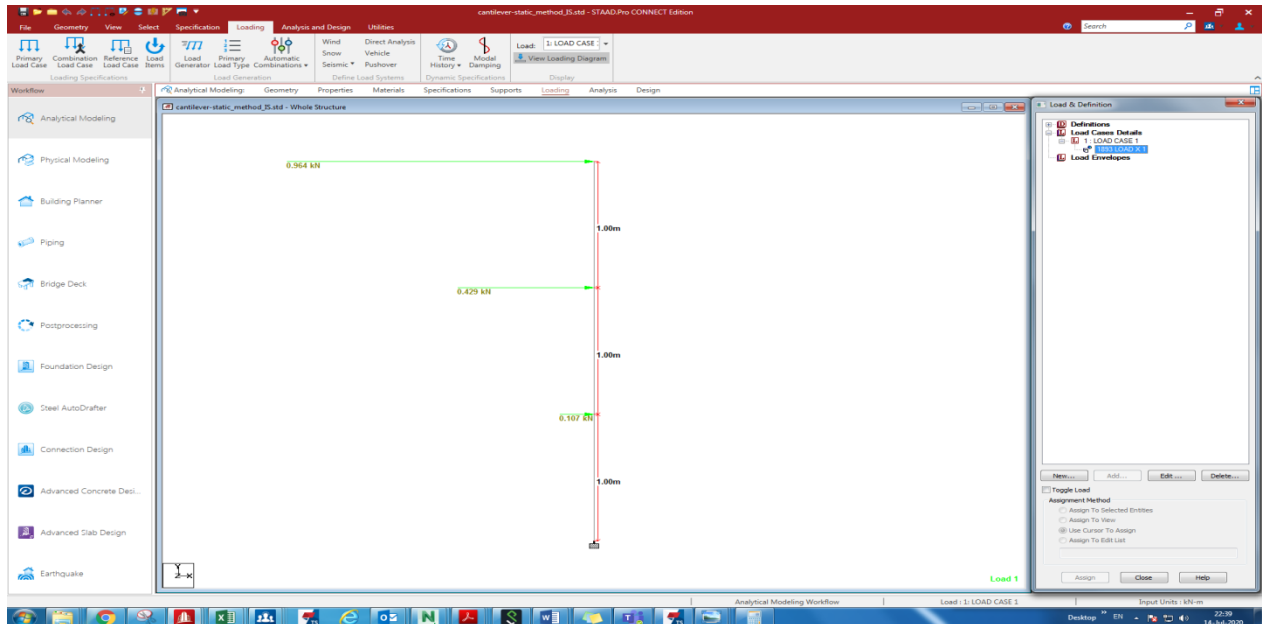


Figure 9: Staad Validation Lateral force distribution story wise

Table 1:Lateral force distribution story wise

Story level	W _i	H _i	W _i * h _i ²	Q _i = $V_B \cdot \frac{W_i h_i^2}{\sum_{j=1}^n W_j h_j^2}$	Q _i STAAD
3	10	9	0.81	0.642	0.964
2	10	6	0.36	0.285	0.429
1	10	3	0.09	0.071	0.107
∑			1.26	1	1.5



From the above table it is seen that the base shear as per manual calculation is match with the base shear as per staad calculations hence it is validated.

V. RESULT AND DISCUSSION

In this chapter results obtained from the software analysis (StaadConnect Edition) are discussed and observed the behavior of the combined and steel Piperackby comparing various parameters the results are explained below,

5.1 For general Load Condition: -

In general load condition various parameters are compared like displacement, Utilization ratio in column, bracing and beam, Story drift and top nodal displacement is compared for both Steel and combined Piperack

Table 5.1:Member utilities for general load condition

Cases	Utilization ratio		
	Beam	Column	Bracing
Steel Piperack	0.984	0.939	0.97
Combined Piperack	0.96	0.857	0.87

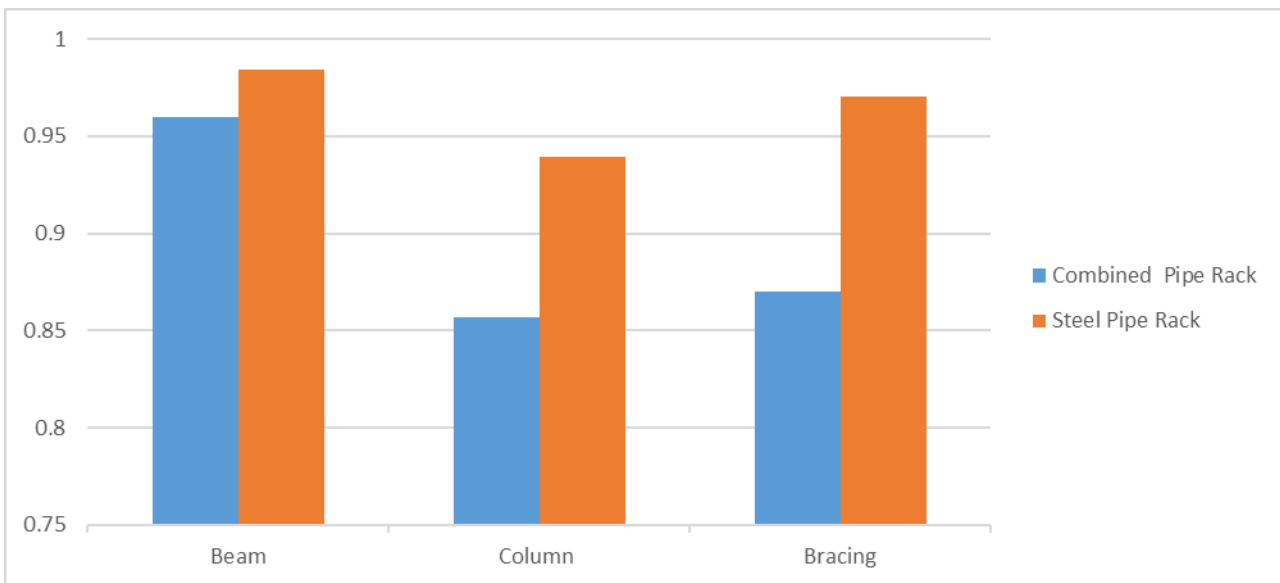


Figure 10: Utilization ratio for general load condition

From the above table and chart, it is seen that the utilization ratios for beam, bracing and column are high in case of steel Piperack than combined Piperackgeneral load conditions.

Table 5.2:Story drift and nodal displacement for general load condition

Cases	Combined Piperack	Steel Piperack
Storey drift (mm)	25.44	26.15
Top nodal displacement (mm)	102.85	116.59

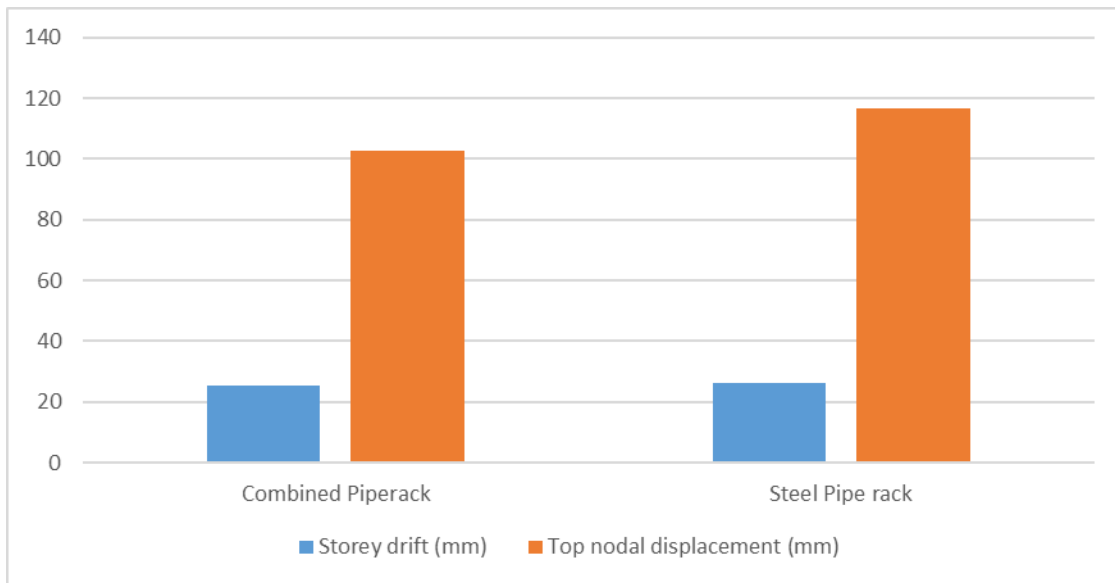


Figure 11: Story drift and nodal displacement for general load condition

From the above table and chart, it is seen that the nodal displacement and story drift for steel Piperack is high than the combined Piperack general load conditions.

Table 5.3: Maximum nodal displacements for general load condition

Cases	Max displacement		
	X direction (mm)	Y direction (mm)	Z direction (mm)
Steel Piperack	116.59	38.99	32.17
Combined Piperack	102.85	38.54	33.33

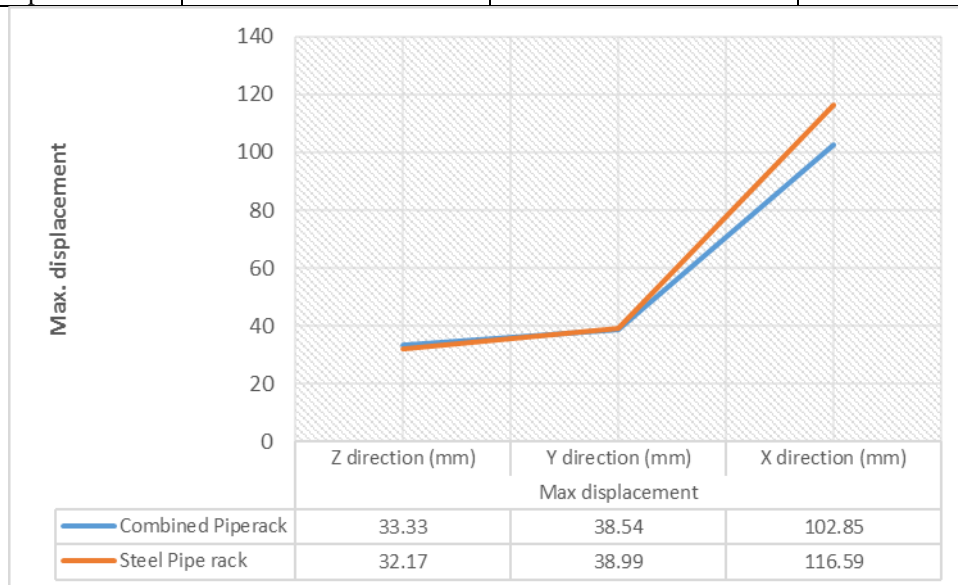


Figure 12: Graph for maximum nodal displacements for general load condition

From the above table and chart, it is seen that the max displacements in X direction and Y direction is high in case of steel Piperack for general load conditions.

5.2 For Emergency Load case 1: -

Table 5.4 :Member utilities for Emergency load case 1 condition

Cases	Utilization ratio		
	Beam	Column	Bracing
Steel Piperack	0.697	0.764	0.843
Combined Piperack	0.533	0.593	0.788

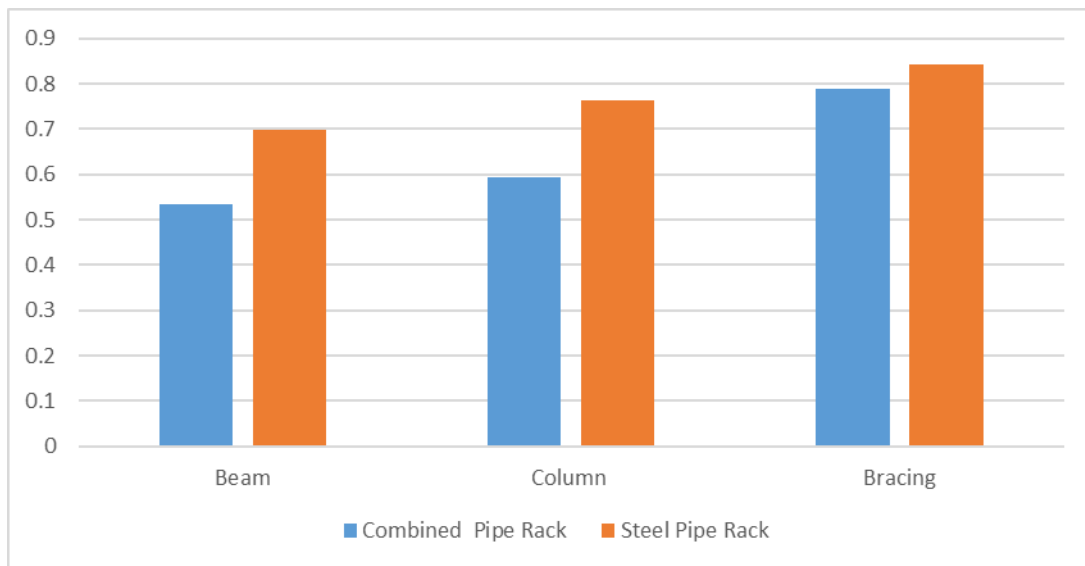


Figure 13: Utilization for Emergency load case 1 condition

From the above table and chart, it is seen that the utilization ratios for beam, column and Bracing are high in case of steel Piperack than combined Piperack general emergency load case one condition. Also, on the other hand the ratios in the bracing is also high in case of steel Piperack compare to combined Piperack.

Table 5.5: Story drift and nodal displacement for Emergency load case 1 condition

Cases	Combined Piperack	Steel Piperack
Storey drift (mm)	6.41	10.11
Top nodal displacement (mm)	29.15	36.72

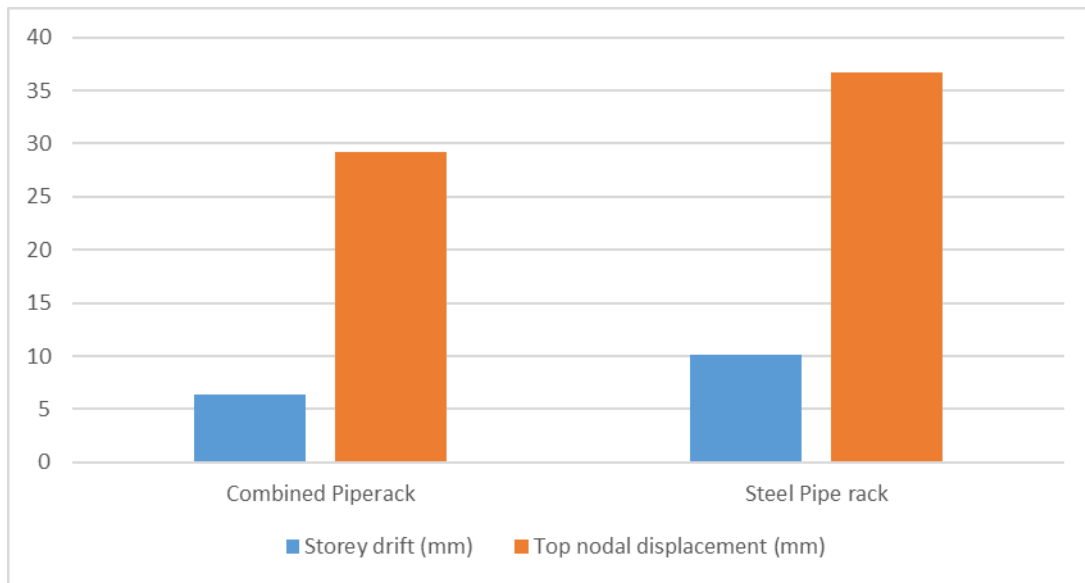


Figure 14: Story drift and nodal displacement for Emergency load case 1 condition

From the above table and chart, it is seen that the nodal displacement and story drift for steel Piperack is high than the combined Piperack for emergency load case one load conditions.

Table 5.6: Maximum nodal displacements for Emergency load case 1 condition

Cases	Max displacement		
	X direction (mm)	Y direction (mm)	Z direction (mm)
Steel Piperack	36.72	14.28	21.57
Combined Piperack	29.15	13.77	28.68

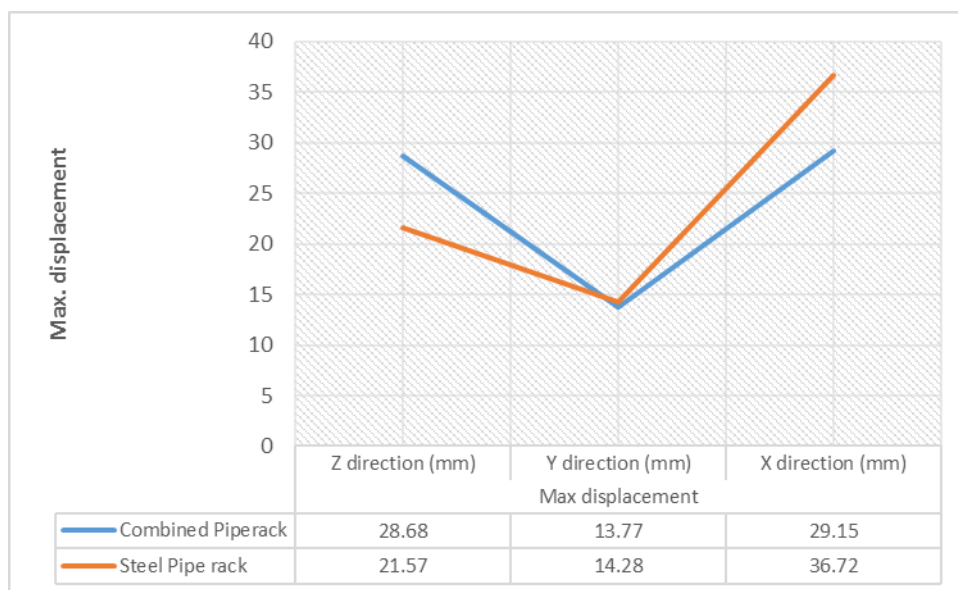


Figure 15: Graph for maximum nodal displacements for Emergency load case 1 condition

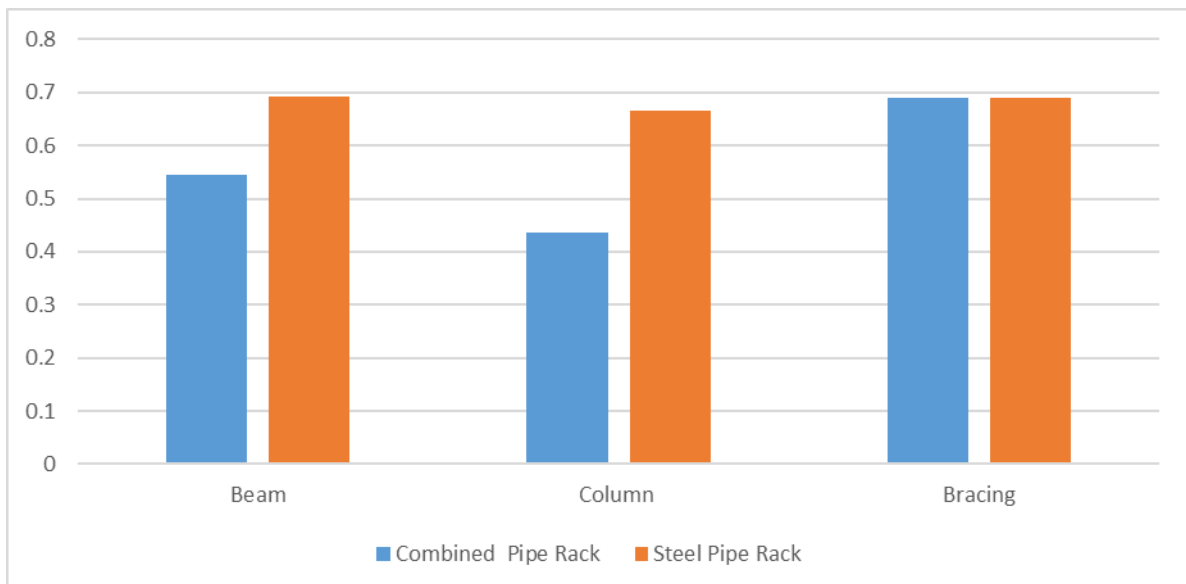


From the above table and chart, it is seen that the max displacements in X direction ad Y direction is high in case of steel Piperack for emergency load case 1.

5.3 For Emergency Load case 2: -

Table 5.7:Member utilities for Emergency load case 2 condition

Cases	Utilization ratio		
	Beam	Column	Bracing
Steel Piperack	0.692	0.666	0.689
Combined Piperack	0.544	0.436	0.689



VI. CONCLUSION

From the analysis of steel and combined Piperack at different three cases the following conclusions are made

- 1) The utilization ratios are less in case of combined Piperack than the steel Piperack for general and emergency cases.
- 2) The story drift and top nodal displacement are less in case of combined Piperack than the steel Piperack for general and emergency cases, this is due to high stiffness of members in the combined Piperack than the steel Piperack.
- 3) The max displacements are less in case of combined Piperack than the steel Piperack for general and emergency cases as the steel Piperack is more flexible than the combined Piperack.
- 4) In Emergency case condition the steel Piperack is poor since it has steel column at base which is having chances of damage to the column in the form of failure of column, local bending or buckle due to vehicular impact load.
- 5) In Emergency case condition two the combined Piperack is better since it has RCC rigid column at base which is resist the vehicular impact loads and avoid damage to the column.

- 6) The Combined Piperack is provide strength and serviceability through its life period as compared to steel Piperack even in case of emergency cases as the RCC columns resist the impact of vehicle (Fire truck) also it has good fire resistance than steel.
- 7) From the analysis and results it is seen that the combined Piperack are more rigid and steel Piperack are flexible this could be leads to serious damage in Oil and gas facility.
- 8) As concrete give better fire protection than the steel the combined Piperack will be more suitable than the steel Piperack.
- 9) As concrete is more fire resistance than steel it is more suitable the construction time will be more than in case of steel Piperack.
- 10) Though the steel Piperack's are costly it takes less time for erection and construction quality can be achieved hence when there is time constrain the steel Piperack is better option.
- 11) The steel tonnage require in case of combined Piperack is less than in case of steel Piperack about 18.79% steel qty is saved in case of combined Piperack.
- 12) The Combined Piperack's are cost effective compared to steel Piperack about 14.54% cost saving is achieved in combined Piperack.
- 13) Where there is hot lines and critical piping combined Piperack is suitable since it has good fire, resistance compared to steel Piperack.
- 14) At hazardous and prone to fire areas Combined Piperack's are suitable than the steel Piperack since it performs good in emergency cases.
- 15) Combined Piperack's are economical also having good structural performance than the steel Piperack so when there is no time constrain and at critical areas it is suitable.
- 16) Combined Piperack's are more durable as it resists the corrosion effect as compared to the steel Piperack.

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