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EFFECTIVE ANALYSIS OF STEEL PIPE RACK FOR THE OIL AND GAS INDUSTRY USING STAADPRO SOFTWARE

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Abstract—

In petrochemical, chemical, and power plants, pipe racks are structures made to hold pipes, instrument cable trays, and power cables. They can also be utilized to support valve access platforms, vessels, and mechanical equipment. It is unclear how the building regulations' design specifications should be applied to pipe racks. Pipe racks ought to be built to withstand a variety of loads, including wind, dead, and live loads. The pipe rack structure is analyzed using STAAD. Pro software. Indian Standard codes were used in the design of the pipe rack members. IS-800-2007 Limit State design methodology. The ISBL pipe rack is the structure. In STAAD, the structure is analyzed as a 3D model. professional software. The analysis and design of the column must be done in STAAD. Although it was released in a Z-direction, the pro is regarded as fixed.

Key words:- Key words: I-section, STAADpro software, steel table, steel pipe rack, Indian standard codes, and oil and gas

1. INTRODUCTION

Piperack piping stands out as an essential and frequently disregarded element in the intricate world of the oil and gas sector. Piperack systems are essential to the safe and effective functioning of oil and gas plants because of their complex network of pipes, supports, and utilities. In addition to guaranteeing the smooth movement of different fluids, these systems provide as the foundation for the distribution of utilities including electrical cables, instrument lines, etc The vast network of pipes that link throughout a processing plant is supported, routed, and arranged by piperacks, which are essentially structural frameworks. They offer the structural integrity required to resist the dynamic forces—such as seismic activity and vibration—that are frequently present in industrial settings.

Piperacks are positioned strategically around the plant for a number of reasons. By ensuring that distinct process lines are kept apart, it lowers the possibility of cross-contamination and improves safety. Additionally, piperack designs take into account factors like overall plant layout, expansion capabilities, and maintenance accessibility. An oil and gas facility's circulatory system is mainly made up of piperack pipeline systems, which make it easier to transfer materials and fluids that are needed for distribution, production, and refinement. Delving into the complex design, functionality, difficulties, and best practices of piperacks begins with an understanding of their essential role in the industry.

In the oil and gas sector, steel pipe racks are essential buildings that support pipes, machinery, and operations in petrochemical facilities, refineries, and offshore platforms. To avoid disastrous breakdowns, environmental risks, and financial losses, it is imperative to guarantee the structural stability and integrity of these pipe racks. Accurate modeling and simulation of pipe rack behavior under varied loads are made possible by sophisticated analysis tools, such as STAAD.PRO.

Advantages: -

• High Strength and Durability:
Steel pipe racks are renowned for their remarkable strength and durability, which enables them to survive severe environmental conditions and support massive pipelines.
• Welding ease:
Pipe rack design and installation are made easier by the relative ease of welding steel.
• Extended Lifespan:
Steel pipe racks are a long-term infrastructure option that can endure for decades with regular maintenance.
• Versatility:
Steel pipe racks can be used to support power cables, instrument cable trays, and pipelines, among other things.
• Recyclability:
Steel is an environmentally responsible choice because it is a completely recyclable material.
• Economical:
Because of their lifespan and durability, steel pipe racks can be an affordable option even with their original cost.

2. STAAD.PRO. :-

STAAD Pro software's main goal is to give structural engineers a complete tool for assessing and creating different kinds of structures, such as buildings, bridges, and other civil engineering projects, while making sure they adhere to safety regulations and design guidelines.

- **System prerequisites**:

1. System software: Windows 7, Windows 8, and Windows 10
2. Processor: at least an Intel Core i3
3. 8 GB or more of RAM
4. Storage: at least 10 GB
5. Graphics: at least 256 MB

1. Specifications for technical aspects:

1. Types of Analysis: Wind, Seismic, Dynamic, Linear, Non-Linear, and More
2. AISC, ACI, ASCE, IBC, and other design codes
3. Materials: aluminum, steel, concrete, timber, and more
4. Section attributes: Integrated attributes for different sizes and shapes
5. Types of Loads: Wind, Seismic, Dead, Live, and Others

3. OBJECTIVE OF PROJECT: -

1) Safety and Structural Stability

Assess the pipe rack's resistance to seismic forces, thermal expansion, wind, dead loads, live loads, and dynamic forces (such as vibrations from equipment).

Verify that the steel structure satisfies safety requirements as well as industry norms and laws.

2) Analysis of Load Distribution

Examine the structure's load distribution and the ability of the joints, beams, and columns to withstand these loads without failing.Take into account the effects of various pipe configurations, including variations in pipe sizes, fluid pressures, and installation specifications.

3) Selection and Optimization of Materials

Optimize the selection of materials (such as steel grades) using STAAD.Pro by taking into account the computed loads and environmental factors (such as corrosion resistance for offshore or extreme climate zones).

4) The feasibility of construction and the ease of fabrication

Verify that the steel pipe rack design can be built, taking into account how simple it is to fabricate and assemble. Any potential issues during construction should be noted in the study, along with suggestions for enhancements.

5) Maintainability and Serviceability

Taking into account elements like accessibility, potential growth, and minimal downtime, make sure the pipe rack design permits simple maintenance and inspection.

These goals can be effectively met by engineers utilizing STAAD.Pro, which can do sophisticated structural analysis and design. This helps engineers to optimize the design, replicate real-world situations, and satisfy the exacting standards of the oil and gas sector.

4. LITERATURE SURVEY :-

1) Jatan Patel, Aditi Sheth, Yogesh Kulkarni (2023)

Pipe racks are structures in the oil and gas, petrochemical, power and chemical industry that are designed to support various process and utility pipes, electrical and instrumentation cable trays. Pipe racks generally transfer fluid/material between equipment and various process units and thus forms the main artery of process units. In any oil and gas or petrochemical industry, the quantum of structural steel of pipe racks contribute around 20–50% of the overall structural steel of the project based on the process unit. Therefore, it was found necessary to study the design of steel pipe racks to optimize the consumption of the structural steel. For developing countries like India, such study will help to reduce consumption of structural steel which will lead to saving in fabrication cost, erection cost of the project

2) P. Zakian, Behnam Ordoubadi, Erfan Alavi (2021)

Design optimization of industrial structures is of great importance for engineers in order to provide a cost-effective structural design. Meanwhile, pipe rack is a skeletal industrial structure subjected to various types of loading such as gravity, seismic, piping, and thermal forces. While there are many studies on design optimization of the most common structures, only a limited number of studies exist on optimal design of industrial structures. In this article, a design optimization problem is proposed for weight minimization of steel pipe rack structures, and then the problem is solved through three meta-heuristic algorithms consisting of a modified particle swarm optimization (PSO), grey wolf optimizer (GWO), and the recently developed improved grey wolf optimizer (IGWO). The optimization problem is in discrete form in order to consider practically available cross-sections for the structural members. Stress ratio, drift, and dimensional constraints are imposed during the optimization. In order to demonstrate the capability and effectiveness of the present design optimization problem, a pipe rack structure is optimized by the proposed algorithms, and the optimized designs are compared to an ordinary design in terms of the structural weight and the status of constraints.

3) M.G.Kaade, A.V.Navale (2019)

Steel pipe racks are commonly used in oil and gas industry to support pipes and cables. They 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 pipe rack with bracings are provided at 6^{th} bay from either side, second is pipe rack with bracings at center and third is pipe rack 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.

4) Ali Reza Keyvani Boroujeni & Mehdi Hashemi, (May 2013)

For this evaluation, two programs are studied; the evaluation of ASCE methods offer of the improved method for supporting structures design. In this study, four pipes and related pipe racks are designed according to scaling method and their vulnerability is assessed based on the linear and nonlinearsimultaneous model of pipes and structures. Analytical results show that scaling method is matched tosimultaneous model and is applicable for design of supporting structure

5) Richarchapterd M. Drake And Robert J. Walter. (2010)

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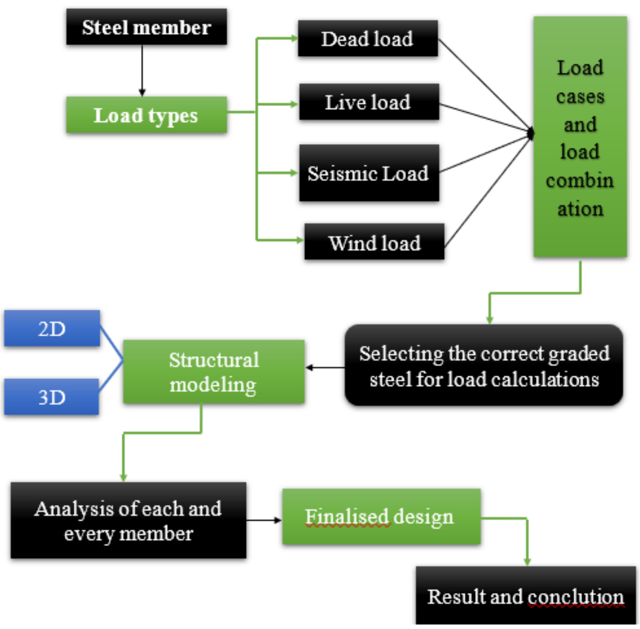
5. METHODOLOGY:-



1. We have attempted to use shear and longitudinal forces in the construction of a steel pipe rack.
2. In pipe stress analysis, apply the load in both longitudinal and transverse directions to calculate shear force and bending moment.
3. Calculate the lateral deflection for the specified pipe rack.
   design of the base plate.

5.1. Load_Cases

- **Dead Load**

Self-weights of Steel members are generated by STAAD as factor 1.15 as per the specified densities of Material. Dead loads other than self-weight are mentioned below taken from

Design Basis –

Loading to account for the cable trays supporting cables, applied as a point load.

Weight of 750mm wide cable trays	= 0.75 kN/m (75 kg/m)
Maximum span of cable trays for electrical	= 2 m
Maximum span of cable trays for instrumentation	= 1.5 m
Point load on support for 750mm wide tray	= 0.75 x 2……… (For 2 m Span) = 1.5 kN
Point load on support for 750mm wide tray	= 0.75 x 1.5……… (For 1.5 m Span) = 1.125 kN
Grating Load	= 0.50 kN/m^2
Steel Staircase	= 1.4 kN/m^2
	= 0.16 kN/m

- **Live Load**

Live Load on Pipe Rack Structures are taken from design basis

Live load on staircase	= 5.0 kN/m^2
Live load on operating platforms (PSV Floors)	= 5.0 kN/m^2
Live Load on Accessway	= 3.0 kN/m^2
Additional point load (of cable tray)	= 0.70 kN

- **Wind Load**

Wind loads on the structure are calculated in accordance with Cl. 2.6 of Doc.no. E23001-COM-CS-BOD- 2001 in compliance with BIS 875 (Part 3). Following are the extract of the critical design parameters.

Table 4 Area Averaging Factor (K_a)
(Clause 7.2.2)

Sl No. (1)	Tributary Area (A) m^2 (2)	Area Averaging Factor (K_a)* (3)
i)	≤10	1.0
ii)	25	0.9
iii)	≥100	0.8

* Linear interpolation for intermediate values of a is permitted.

Basic Wind Speed Vb	= 47 m/sec
Risk Coefficient, k1	= 1.0 for Permanent Structure = 1.07 for Prilling Tower
Topography Factor, k3	= 1.0
Importance factor for Cyclonic region, k4	= 1.0

Terrain roughness and Height factor k2 shall be considered for Terrain Category-2 as per table 2 of IS 875 (Part 3).

(Ref. Cl. 6.3 & 7.2 of IS 875 (Part-3))	
Design Wind Speed, Vz	= Vb x k1 x k2 x k3 x k4
Wind Pressure at ht. Pz in N/m^2	= 0.6 x Vz^2
And Design Wind Pressure Pd in N/m^2	= kd x ka x kc x Pz
Wind Directionality Factor, kd	= 0.9 as per CI 7.2.1 of IS 875 Part 3 = 1.0 (for circular or near circular forms)
Area averaging factor, ka referred for respective area contribution	= 1.0 (Table 4 of IS 875 Part 3 shall be
Combination factor kc	= 1.0 as per Cl 7.3.3.13 of IS 875 Part 3

- **Seismic Load**

Seismic load will be calculated in accordance with IS 1893 Part-I & Part-IV and the following parameters;

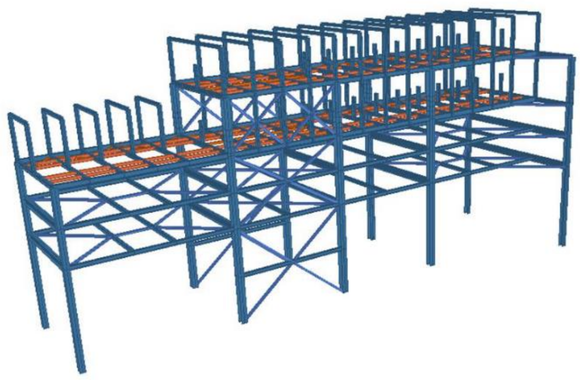


Fig.01:- 3D Pipe Rack Model

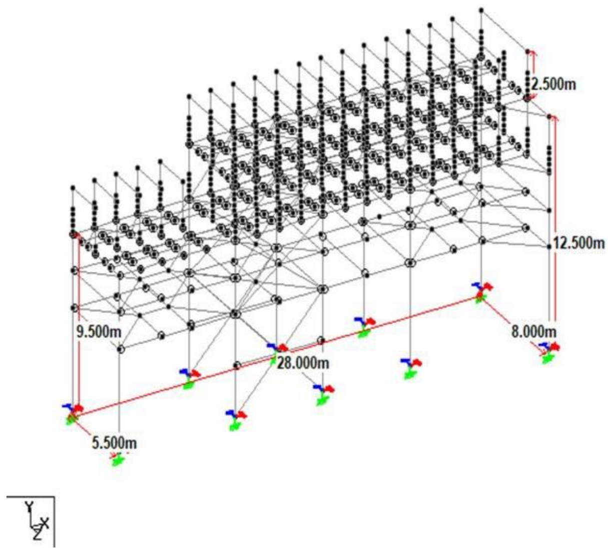


Fig.02:-Node Number of Structure

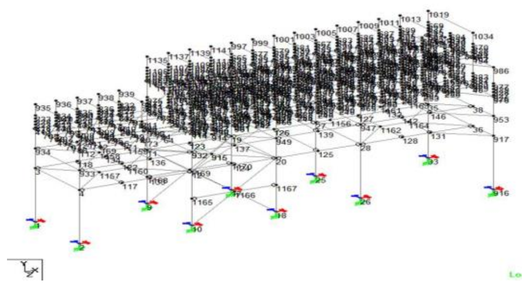
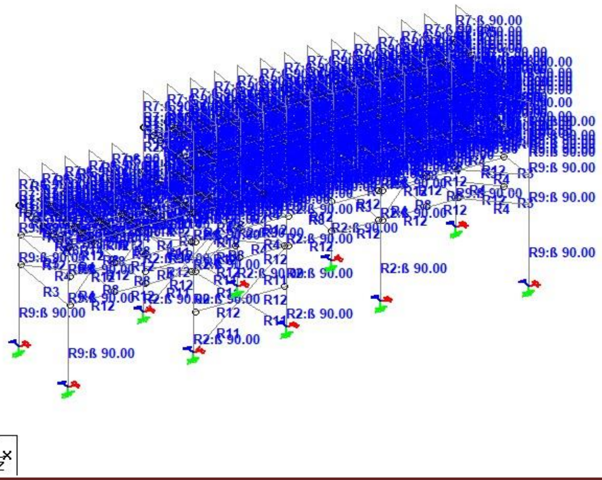


Fig.03:-Member Number Of Section



Type of structure	Industrial steel pipe rack
Total height of structure	15m
Length of rack from "I to J"	8m
Length of rack from "J to K"	6m
Length of rack from "K to L"	6m
Length of rack from "L to M"	8m
Total length of pipe rack	28m
Width of rack point "I"	5.5m
Width of rack point "M"	8m

6. RESULT AND CONCLUSION

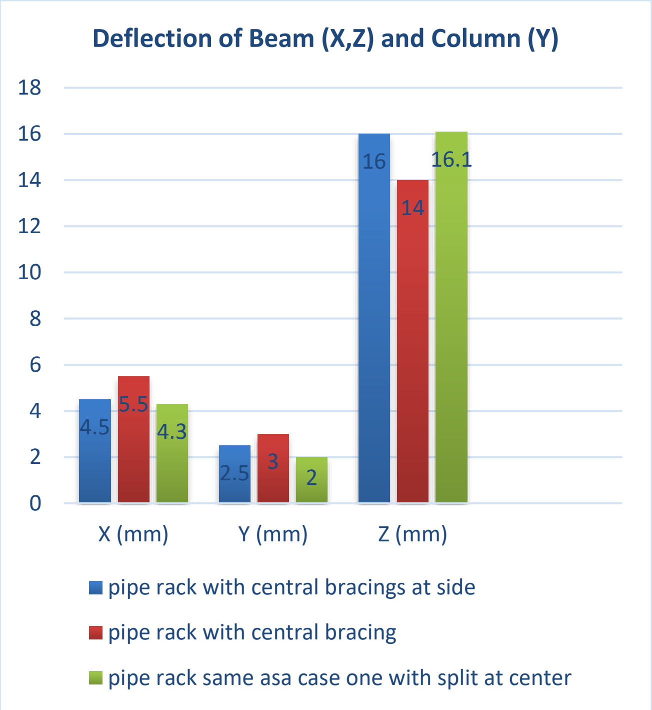
6.1 Result

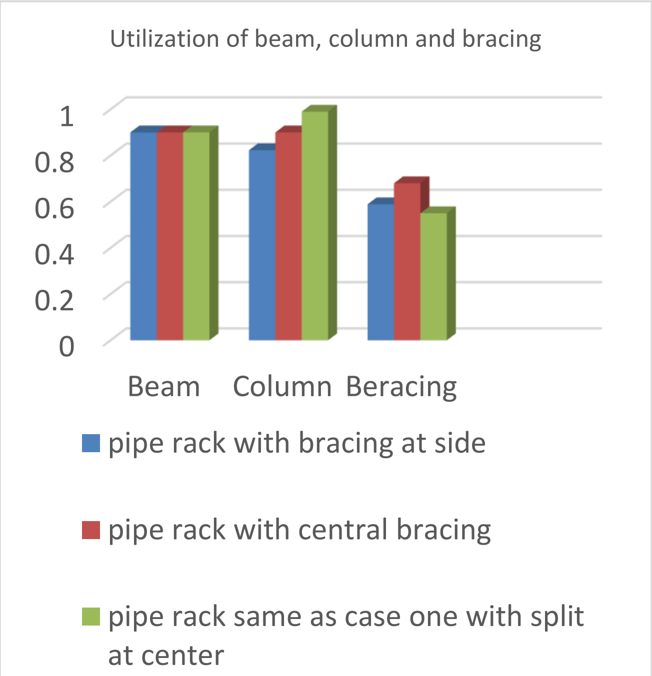
- Using STAAD, structural analysis is performed. Pro. According to their individual IS provisions, every component of the structure is safe from design loads and load combinations.
- For the utilization ratio on the design and deflection checks on the analysis, see the summary below.
- Check for deflection.

Allowable Deflection = Height /200 ------- (Height of structure in mm)

SR.no.	Piperack	Height	Allowable Deflection (mm)	Maximum deflection on X direction (mm)	Maximum deflection on Z direction (mm)
1	MPR	12.3	41	0.130	1.303
2		9.3	6.5	0.100	0.729

Sr.no.	Member Type (used for)	Section size	Allowable Ratio	Maximum Ratio
1	BEAM	UB203X133X30	1.0	0.876
2		UB305X165X46	1.0	0.787
3		UB305X165X54	1.0	0.89
4		UB56X171X51	1.0	0.86
5		ISMC100	1.0	0.613
6		ISMC150	1.0	0.731
7		UB406X178X60	1.0	0.966
8	COLUMN	UC152X152X30	1.0	0.545
9		UC203X230X60	1.0	0.75
10		UC254X254X89	1.0	0.838
11	HB & VB	UBT133X101X15	1.0	0.746
12	HB & VB	UBT146X127X18	1.0	0.701
13	HB & VB	UBT165X152X23	1.0	0.738





6.2 Conclusion

STAAD was used to analyze the steel pipe rack.According to the applicable IS standards, pro software shows that every structural element has been effectively designed and falls within the permitted ranges of deflection and usage ratios. The design's structural safety and serviceability are validated by the deflection values and usage ratios for the braces, columns, and beams.

- Important lessons learned include:
  For modeling, analyzing, and constructing intricate pipe rack systems under a range of loads—including dead, live, wind, seismic, and equipment loads—STAAD.Pro proven to be an effective tool.

- In order to guarantee serviceability under anticipated operating circumstances, every structural part underwent deflection checks.

- In order to maximize material use while maintaining structural integrity, utilization ratios for all essential members were within the safe design bounds.

- The design satisfies national standards for structural safety and performance by adhering to IS 800:2007 and other pertinent codes.

- The outcomes support the use of software-based modeling in industrial applications for pipe rack design that is both economical and time-efficient.

7. FUTURE SCOPE: -

- Industrialization and Infrastructure Development:
The demand for dependable and long-lasting piping systems, backed by steel pipe racks, will only increase as economies and infrastructure projects grow.

- Demand from the Energy Sector:
The oil and gas sector, which uses a lot of steel pipes, is expected to keep growing and will need reliable and effective pipe rack systems.

- Building and Manufacturing:
Steel pipes are essential for many building and manufacturing processes, and there will probably be a rise in demand for these pipes as well as the racks that hold them.

- Technological Developments and Modularization:
Modular pipe rack systems are becoming more and more appealing because to their advantages, which include quicker construction, lower prices, and increased flexibility.

- Seismic Safety:
Sturdy and seismically resistant pipe rack designs are essential in earthquake-prone areas.

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