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DYNAMIC ANALYSIS USING PIPE RACK SYSTEM SUBJECTED TO SEISMIC EXCITATIONS

Sudarshan Jaydeep Borkar[1], **Shashir Daule**[2]

Student, Department of Civil Engineering, Dr. Vitthalrao Vikhe Patil College of Engineering, Vilad Ghat, Ahmednagar, Maharashtra 414111[1]

Asst. Prof., Department of Civil Engineering, Dr. Vitthalrao Vikhe Patil College of Engineering, Vilad Ghat, Ahmednagar, Maharashtra 414111[2]

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Abstract: Piperacks are the most prevalent structure in industrial plants such as oil and gas, petrochemicals, and refineries that transport large diameter pipes from one piece of equipment to another piece of equipment or from one unit to another unit. Pipe racks are the lifeblood of oil and gas plants, and as such, meticulous planning and analysis are required for each industrial project. Due to the fact that the bulk of material is involved, there will be an influence on the project's cost, and so optimization is necessary. Pipe racks must be constructed to accommodate the bulk of loads, such as principal essential loads and pipe loads. The pipe rack is analysed with appropriate loads and configurations utilising a variety of software packages such as STAAD Pro, ANSYS, and SAP. Members of the pipe racks have been developed according to Indian Standard, American Standard, or British Standard norms, depending on the project's requirements and region. The pipe racks' members must be adequate in terms of strength, vertical and horizontal deflection. Pipe racks' total drift limit must be kept within the specified range. STAAD Pro software was used to analyse and design a piperack for an ongoing international project. Pipe rack, pipe sustained loads, pipe operating loads, pipe test loads, pipe frictional forces, pipe anchor forces, grids, cross beams, cable trays, bracings, moment connections, and shear connections, and Staad Pro V8I.

Keywords: *Pipe Rack System, Dynamic Analysis, Staad Pro V8I*

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I INTRODUCTION

Pipe rack is concrete or steel structure which carries multiple pipes carrying liquid or gas in different tiers and also carries Electrical/Instrument/Telecom Cable trays and supports Auxiliary Equipment like Air Cooler, Pressure sustaining valves etc. with service platforms and walkways. Pipe racks carry large diameter to small bore lines with liquid or gas from one Equipment to another Equipment or from one unit to another unit. These are necessary for carrying large number of Process lines, Utility lines, Flare lines etc. Pipe racks are useful to carry Electrical, Instrumentation and Telecom Cable trays from one Equipment to Equipment and from one unit to another unit. Pipe racks are also useful for supporting Auxiliary Equipment like Air Coolers, Pressure release valves etc.

Objective

The main objectives of the thesis have been presented as follows.

1)Analyze and Design of steel pipe rack members using manual analysis as per codes specifications ASCE 07 and PIP(2007)STC PIP 01015.

2) Dynamic Analysis of Pipe Rack System Subjected To Seismic Excitations using STAAD Pro V8I.

3) Comparison of Manual Method of pipe rack with STAAD Pro V8I.

II GENERAL ARRANGEMENT VIEWS

As seen in Figure 1, this pipe rack supports pipes at the following tier elevations: TOS (Top Of Steel) at 111.600, TOS (Top Of Steel) at 109.00, TOS (Top Of Steel) at 107.000, and TOS (Top Of Steel) at 104.400. This pipe rack is modelled in STAAD PRO, and all reactions, forces, and utility ratios are utilised to illustrate the thesis. The length of the PIPE RACK is 54m, as seen in Figure 1. This pipe rack was designed and modelled using load data provided by the mechanical department, and the load of liquid flowing through pipes provided by the piping department, as well as data provided by the vendor and client requirements, client specifications, and civil design principles (ASCE 7-02), PIP(2007).

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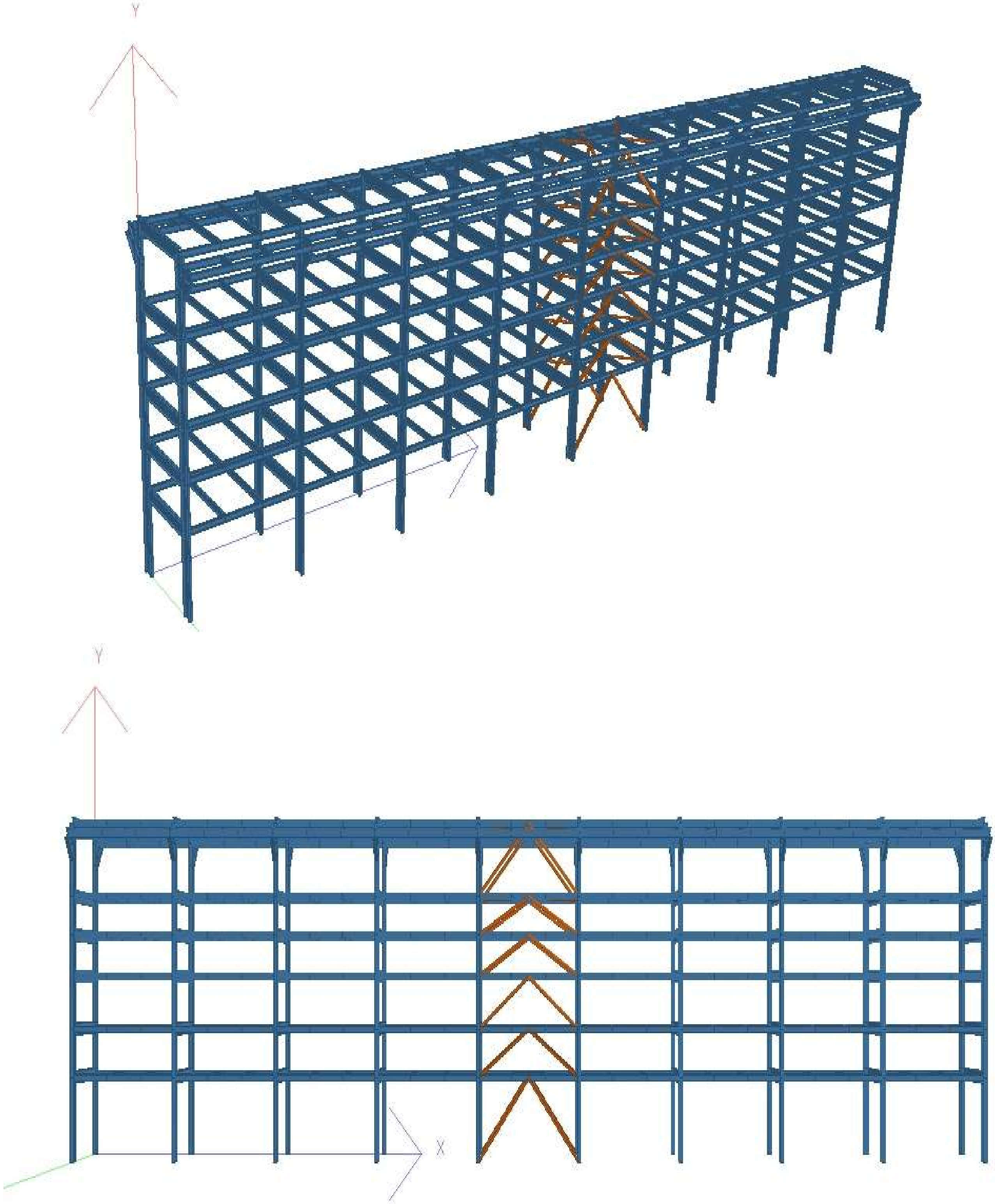


Figure 1 Structure

There are ten grids running longitudinally (Grid-1, Grid-2, Grid-3, Grid-4, Grid-5, Grid-6, Grid-7, Grid-8, Grid-9, Grid-10), each grid separated by a distance of six meters. Thus, the pipe rack's entire length is 54 meters. The analysis and assembly of beams, columns, and bracings (longitudinal, intermediate, horizontal, and plan) has been completed, and STAAD assembly images are supplied above.

1) Central bay has been considered as the anchor bay.

2) Plane bracing and vertical bracing are included to meet design requirements and to provide clearance for pipe routing.

3) Supports for cable trays are supplied at a maximum spacing of 3m.

4) The columns are oriented and arranged in accordance with their maximal moment of inertia.

5) Due to the pipe rack's width exceeding 4m in both bays. Thus, both bays are accessible to humans below the lower decks.

6) The biggest pipe diameter 30" passes through Tier-1 Grid-8; the load is supported by the universal beam UB610X305X149.

7) Moment and shear connections are supplied in accordance with the column and beam's design specifications.

8) Vertical bracing is provided between Grid-5 and Grid-6 to accommodate the passage of 18" and 24" diameter pipes and cable trays through these grids.

III DESIGN METHODOLOGY

The design of the pipe rack is done on the basis of the standard load data given from the mechanical and piping department. The design is followed as per the specifications from the ASCE 07 and PIP(2007)STC PIP 01015.However the design may also depends upon the

1) Clients financial status and estimation,

2) The pipe rack local environment conditions,

3) Clients specifications, civil design basis.

4) Mechanical load, General arrangement drawings.

5).From the data given from vendor.

Design Loads Considered And Code Specifications For These Loads:-

1) Dead Load –DL: Superstructure weight consisting of self-weight of the structural steel members, handrails & grating weight shall be considered as dead load. The grating self weight shall be considered as 0.5 kN/m2.Additional load of 12%of the self-weight of structure shall be considered towards connection plates.

2) Live Load –LL:Live loads on the platforms, walkways and staircase are to be considered based on the usage and from design basis.

3) Fire Proofing Load –FP: The weight of fire proofing material applied to protect the structure against fire hazards shall be taken into account. Fireproofing weights shall be determined based on 34mm thick Fendolite -MII (Unit weight = 7 kN/m3) applied in the shape of the steel profile for sizes more than 200mm (in either dimension). For steel profile of sizes 200mm or less solid fill shall be considered. Fireproofing shall be provided based on fire hazard assessments. This load shall be included in DL case.

4) Pipe Empty Load –PE: The Blanket load of 1.1 Kn/m2for pipes less than 12 inch and actual empty weight for pipes greater than or equal to 12inch as given by piping discipline.

5) Pipe Operation Load –PO: The Blanket load of 0.6Kn/m2for pipes less than 12 inch and actual content weight for pipes greater than or equal to 12inch as given by piping discipline.

6) Pipe Hydro Test Load –PT:PT is the weight of water in the pipe during the hydro-test. For hydro-test it is assumed that the two largest pipe sizes per tier on the rack are tested at the same time. All other lines are considered empty. For pipes less than12 inch diameter, a uniformly distributed load of 0.6 kN/m2may be considered when a more definitive value for the weight of water in the pipes cannot be established. The loads

from the weight of water in the lines of 12 inch diameter and above shall be applied as concentrated loads at the pipe locations as given on the piping layouts and load data.

7) Longitudinal Pipe Friction Forces (PFL):A longitudinal horizontal force due to pipe friction equal to 10% of the pipe operating weight (empty pipes + pipe contents) shall be applied on each pipe supporting beam of the pipe rack. For small bore lines (less than 12 inch dia)above loads shall be taken as uniformly distributed. The friction loads shall be considered to be acting at the respective pipe locations on the beam.

8) Transverse Pipe Friction Forces (PFT):A transverse horizontal force due to friction equal to 5% of the pipe operating weight (empty pipes + pipe contents) shall be applied on each pipe supporting beams of the pipe rack. For small bore lines (less than 12 inch dia) above loads shall be taken as uniformly distributed.

9) Pipe Anchor Forces -PAL & PAT: Longitudinal and transverse anchor/guide forces (PAL & PAT) shall be the greater of:

a) Loads as specified by Piping Department based on stress analysis results.

b) Longitudinal anchor load (PAL) equal to 10% of the pipe operating (emptypipes + pipe contents) weight per tier and transverse anchor load (PAT) equal to5% of the pipe operating weight per tier.

WIND LOADS ON PIPE RACK

A. Wind on Pipe rack

Find loads on pipe rack frame members shall be calculated using a pressure coefficient (Ct) of 1.2 for circular sections less than 150 mm diameter, 0.8 for circular sections greater than or equal to 150 mm diameter and 2.0 for flat shapes and rolled structural shapes. The effect of increased width / depth of member size due to fireproofing shall be accounted for. Normal wind forces shall be considered to act during the hydro-testing of the pipes.

Transverse Wind Loads (WT) on Cable Trays

Wind load on the cable trays at each tier shall be determined as follows:

Fdesign = qh*Ct*D*Lt

Where,

qh = Design wind pressure a height

h

Ct = 2 + B/(25*D) ≤ 4

B = Total width across cable trays

D = depth of cable tray

Lt =the tributary length of cable trays

IV RESULTS AND DISCUSSION

The pipe rack is a global pipe rack project based in Saudi Arabia. This pipe rack is constructed in accordance with the provisions and standards of ASCE 7-05 as well as PIP (2007)PIP STC01015 and is modelled in STAAD PRO V8i software. The ASCE guideline should be regarded as a reference manual, not as a design manual. The STAAD PRO V8i programme analysed this pipe rack using the LRFD (Load Resistant Factor Design) approach specified in the AISC 360-10.

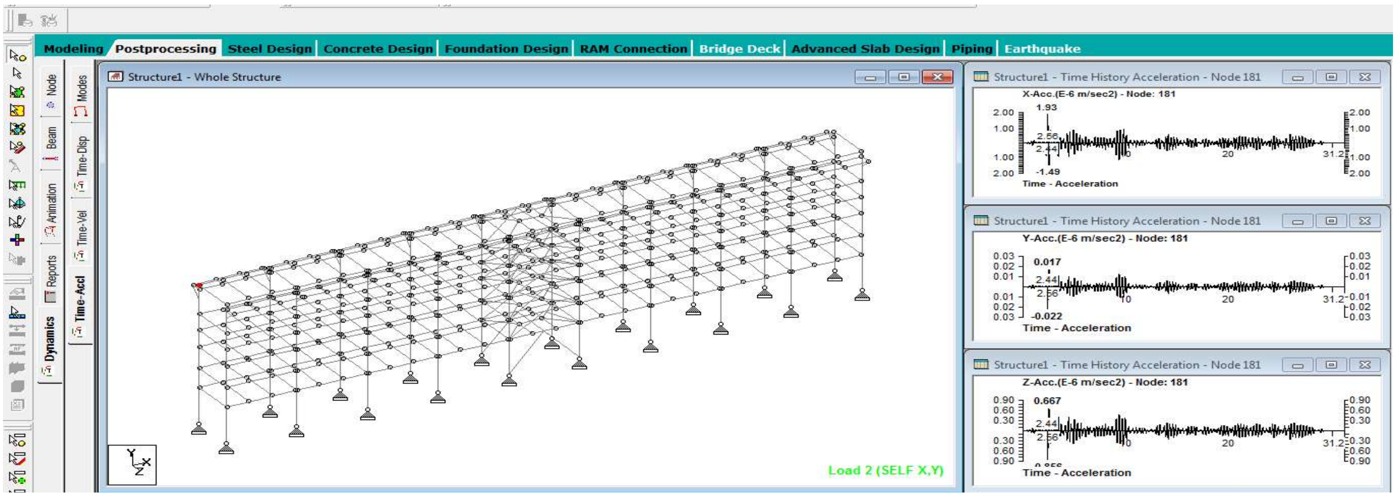


Figure 1 Model

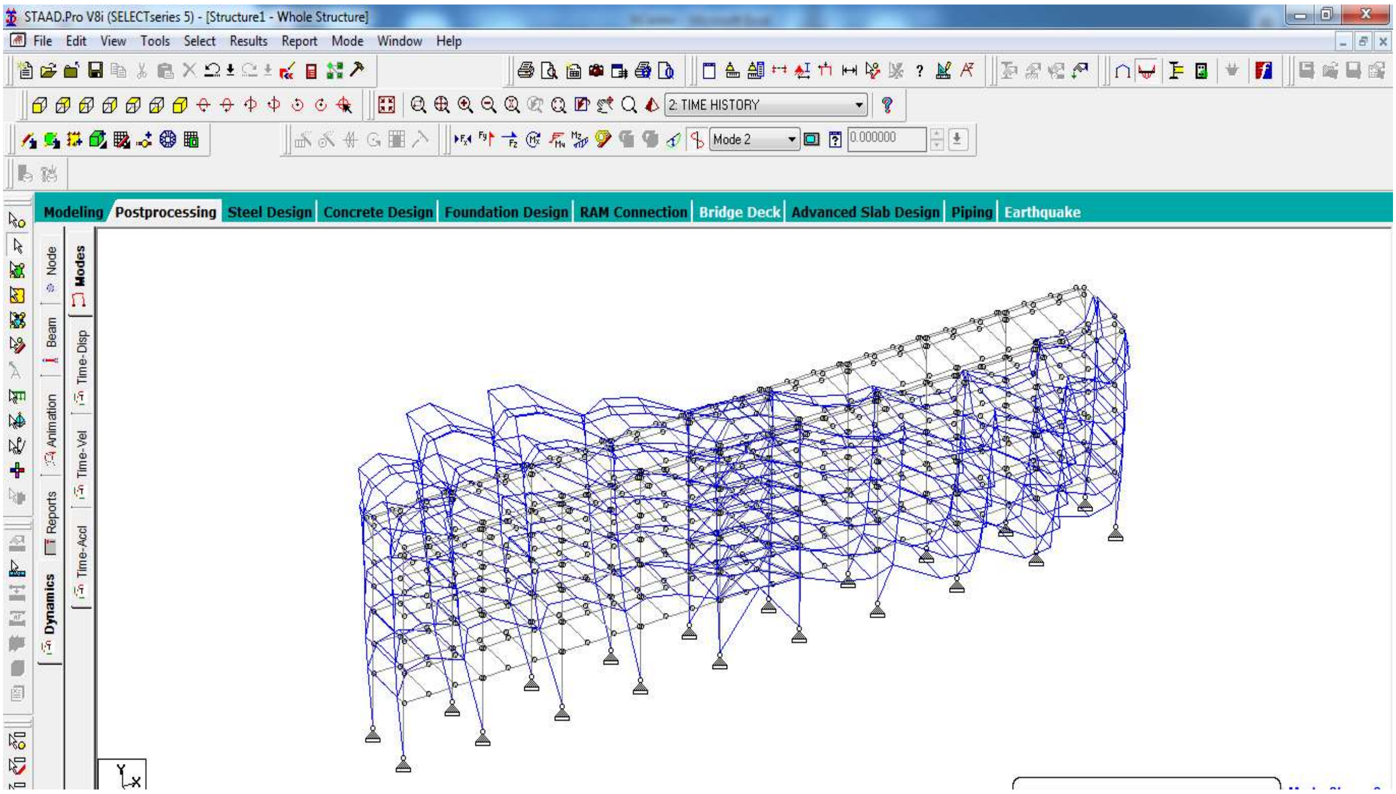


Figure 2 Time History Analysis

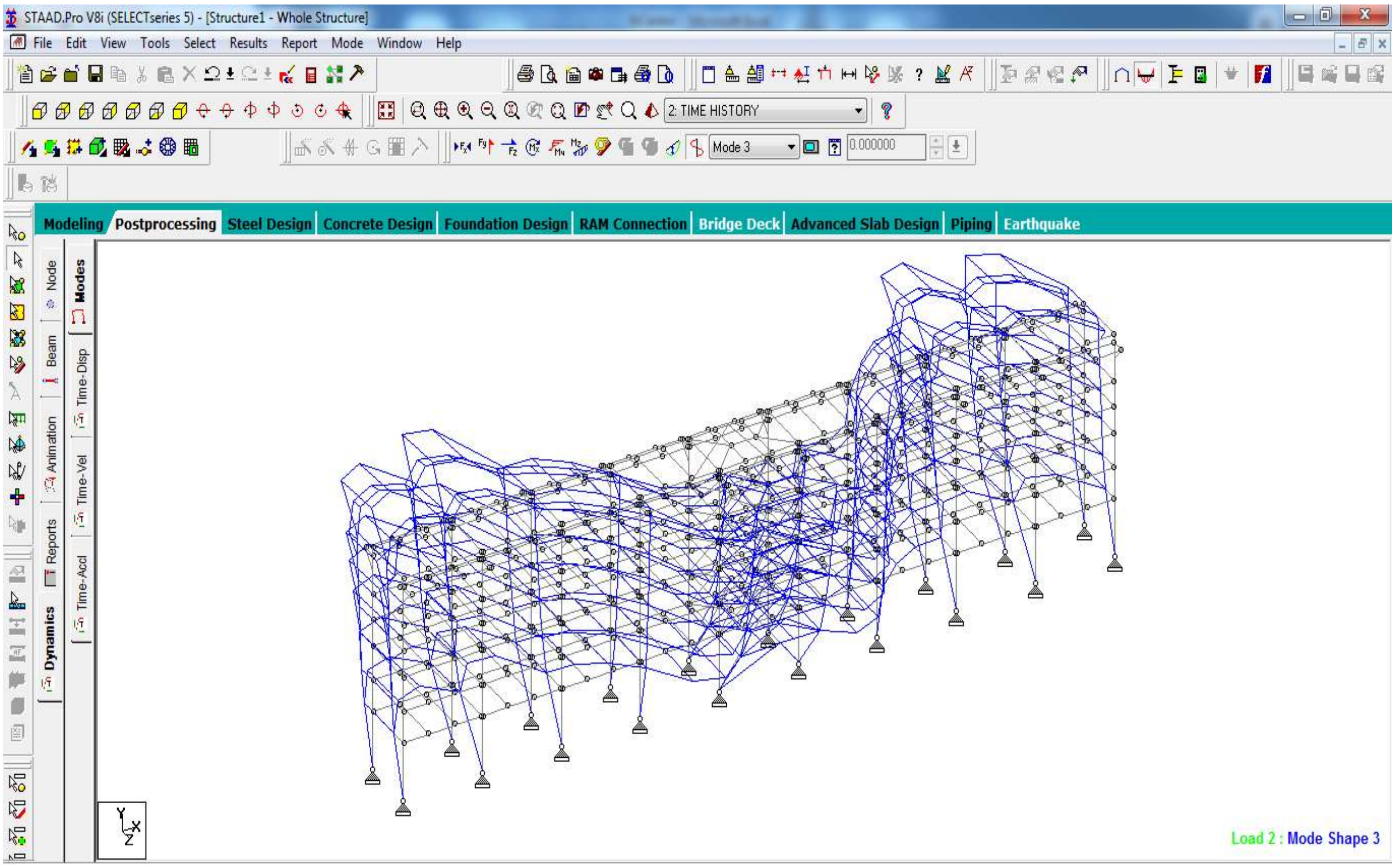
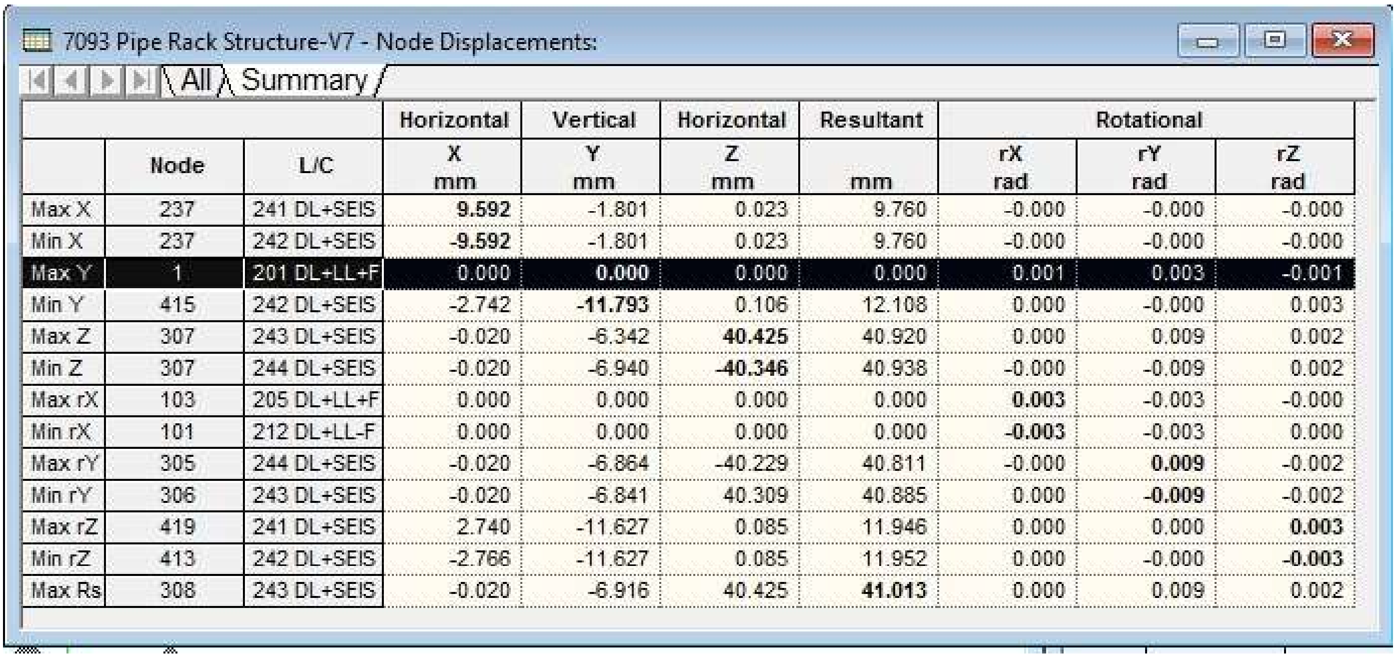
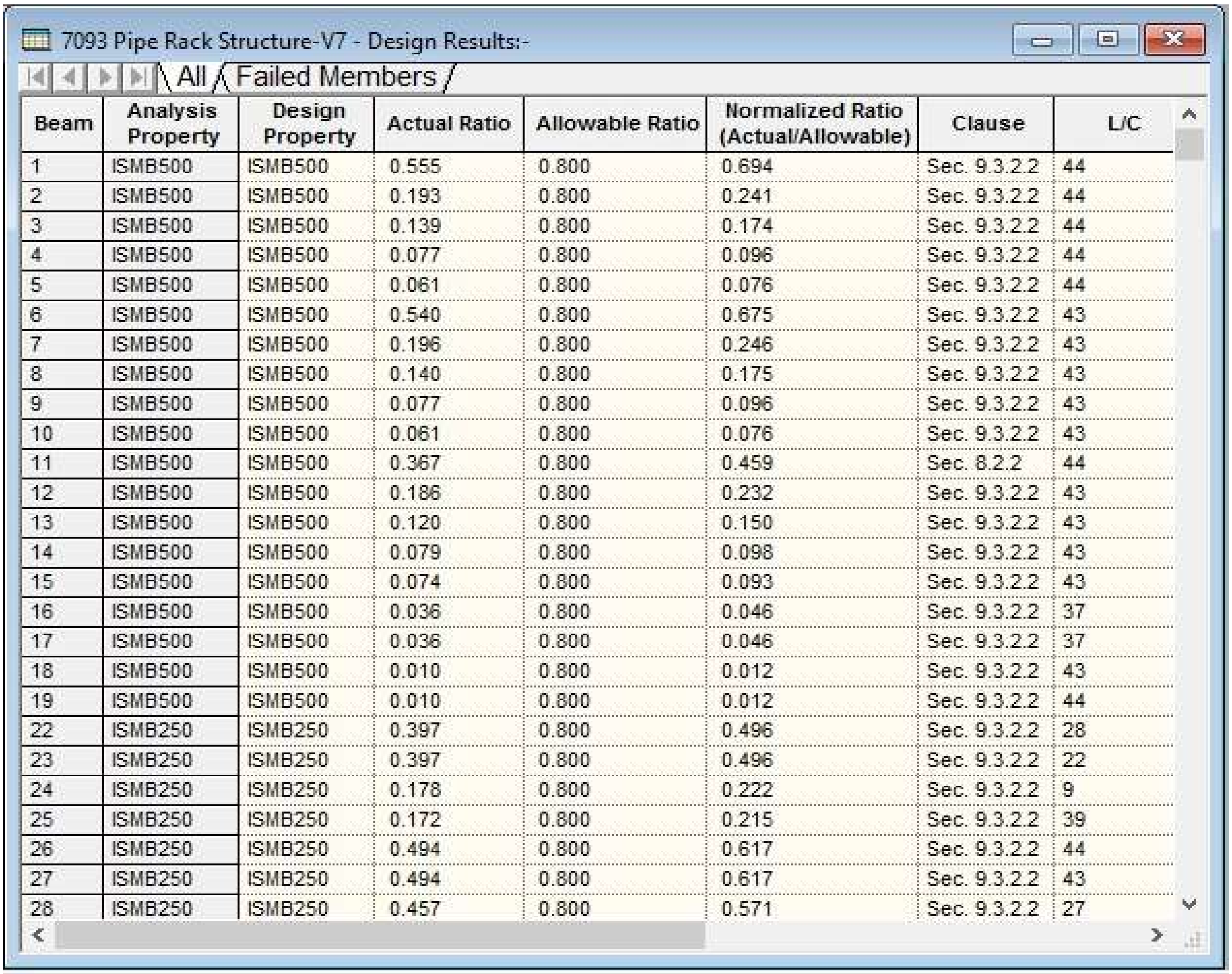


Figure 3 Time History Analysis



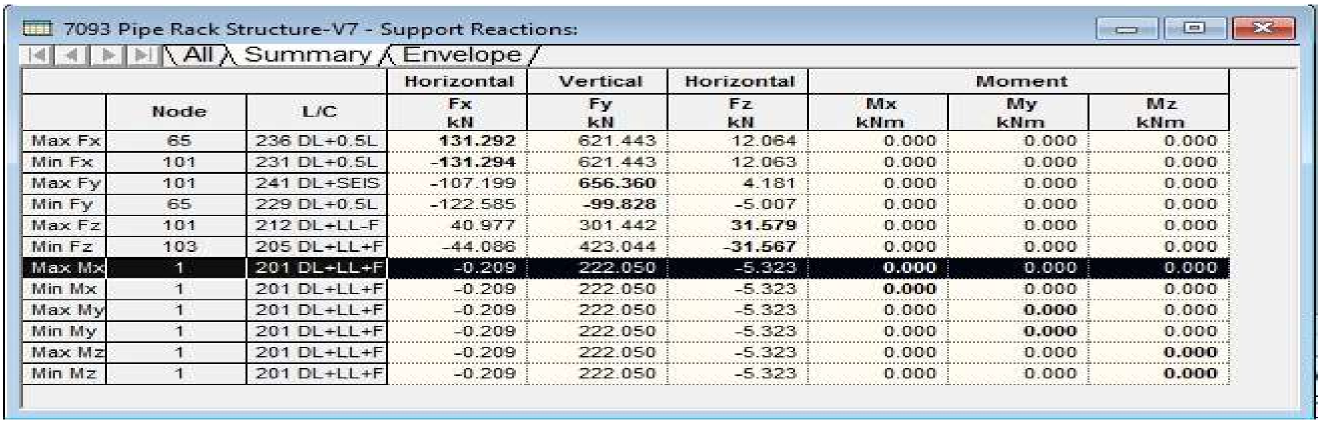
			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	237	241 DL+SEIS	**9.592**	-1.801	0.023	9.760	-0.000	-0.000	-0.000
Min X	237	242 DL+SEIS	**-9.592**	-1.801	0.023	9.760	-0.000	-0.000	-0.000
Max Y	1	201 DL+LL+F	0.000	**0.000**	0.000	0.000	0.001	0.003	-0.001
Min Y	415	242 DL+SEIS	-2.742	**-11.793**	0.106	12.108	0.000	-0.000	0.003
Max Z	307	243 DL+SEIS	-0.020	-6.342	**40.425**	40.920	0.000	0.009	0.002
Min Z	307	244 DL+SEIS	-0.020	-6.940	**-40.346**	40.938	-0.000	-0.009	0.002
Max rX	103	205 DL+LL+F	0.000	0.000	0.000	0.000	**0.003**	-0.003	-0.000
Min rX	101	212 DL+LL-F	0.000	0.000	0.000	0.000	**-0.003**	-0.003	0.000
Max rY	305	244 DL+SEIS	-0.020	-6.864	-40.229	40.811	-0.000	**0.009**	-0.002
Min rY	306	243 DL+SEIS	-0.020	-6.841	40.309	40.885	0.000	**-0.009**	-0.002
Max rZ	419	241 DL+SEIS	2.740	-11.627	0.085	11.946	0.000	0.000	**0.003**
Min rZ	413	242 DL+SEIS	-2.766	-11.627	0.085	11.952	0.000	-0.000	**-0.003**
Max Rs	308	243 DL+SEIS	-0.020	-6.916	40.425	**41.013**	0.000	0.009	0.002

Figure 4 Result of Node Displacement .



Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
1	ISMB500	ISMB500	0.555	0.800	0.694	Sec. 9.3.2.2	44
2	ISMB500	ISMB500	0.193	0.800	0.241	Sec. 9.3.2.2	44
3	ISMB500	ISMB500	0.139	0.800	0.174	Sec. 9.3.2.2	44
4	ISMB500	ISMB500	0.077	0.800	0.096	Sec. 9.3.2.2	44
5	ISMB500	ISMB500	0.061	0.800	0.076	Sec. 9.3.2.2	44
6	ISMB500	ISMB500	0.540	0.800	0.675	Sec. 9.3.2.2	43
7	ISMB500	ISMB500	0.196	0.800	0.246	Sec. 9.3.2.2	43
8	ISMB500	ISMB500	0.140	0.800	0.175	Sec. 9.3.2.2	43
9	ISMB500	ISMB500	0.077	0.800	0.096	Sec. 9.3.2.2	43
10	ISMB500	ISMB500	0.061	0.800	0.076	Sec. 9.3.2.2	43
11	ISMB500	ISMB500	0.367	0.800	0.459	Sec. 8.2.2	44
12	ISMB500	ISMB500	0.186	0.800	0.232	Sec. 9.3.2.2	43
13	ISMB500	ISMB500	0.120	0.800	0.150	Sec. 9.3.2.2	43
14	ISMB500	ISMB500	0.079	0.800	0.098	Sec. 9.3.2.2	43
15	ISMB500	ISMB500	0.074	0.800	0.093	Sec. 9.3.2.2	43
16	ISMB500	ISMB500	0.036	0.800	0.046	Sec. 9.3.2.2	37
17	ISMB500	ISMB500	0.036	0.800	0.046	Sec. 9.3.2.2	37
18	ISMB500	ISMB500	0.010	0.800	0.012	Sec. 9.3.2.2	43
19	ISMB500	ISMB500	0.010	0.800	0.012	Sec. 9.3.2.2	44
22	ISMB250	ISMB250	0.397	0.800	0.496	Sec. 9.3.2.2	28
23	ISMB250	ISMB250	0.397	0.800	0.496	Sec. 9.3.2.2	22
24	ISMB250	ISMB250	0.178	0.800	0.222	Sec. 9.3.2.2	9
25	ISMB250	ISMB250	0.172	0.800	0.215	Sec. 9.3.2.2	39
26	ISMB250	ISMB250	0.494	0.800	0.617	Sec. 9.3.2.2	44
27	ISMB250	ISMB250	0.494	0.800	0.617	Sec. 9.3.2.2	43
28	ISMB250	ISMB250	0.457	0.800	0.571	Sec. 9.3.2.2	27

Figure 5 Utilisation Ratio of members



7093 Pipe Rack Structure-V7 - Support Reactions:

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	65	236 DL+0.5L	**131.292**	621.443	12.064	0.000	0.000	0.000
Min Fx	101	231 DL+0.5L	**-131.294**	621.443	12.063	0.000	0.000	0.000
Max Fy	101	241 DL+SEIS	-107.199	**656.360**	4.181	0.000	0.000	0.000
Min Fy	65	229 DL+0.5L	-122.585	**-99.828**	-5.007	0.000	0.000	0.000
Max Fz	101	212 DL+LL-F	40.977	301.442	**31.579**	0.000	0.000	0.000
Min Fz	103	205 DL+LL+F	-44.086	423.044	**-31.567**	0.000	0.000	0.000
Max Mx	1	201 DL+LL+F	-0.209	222.050	-5.323	**0.000**	0.000	0.000
Min Mx	1	201 DL+LL+F	-0.209	222.050	-5.323	**0.000**	0.000	0.000
Max My	1	201 DL+LL+F	-0.209	222.050	-5.323	0.000	**0.000**	0.000
Min My	1	201 DL+LL+F	-0.209	222.050	-5.323	0.000	**0.000**	0.000
Max Mz	1	201 DL+LL+F	-0.209	222.050	-5.323	0.000	0.000	**0.000**
Min Mz	1	201 DL+LL+F	-0.209	222.050	-5.323	0.000	0.000	**0.000**

Figure 6 Support Reaction Summary.

Total Dısplacement mm

Table 1 Total Displacement mm

Total Displacement mm		
Double Bracing	**Single Bracing**	**Without Bracing**
13.1	29.3	30.5

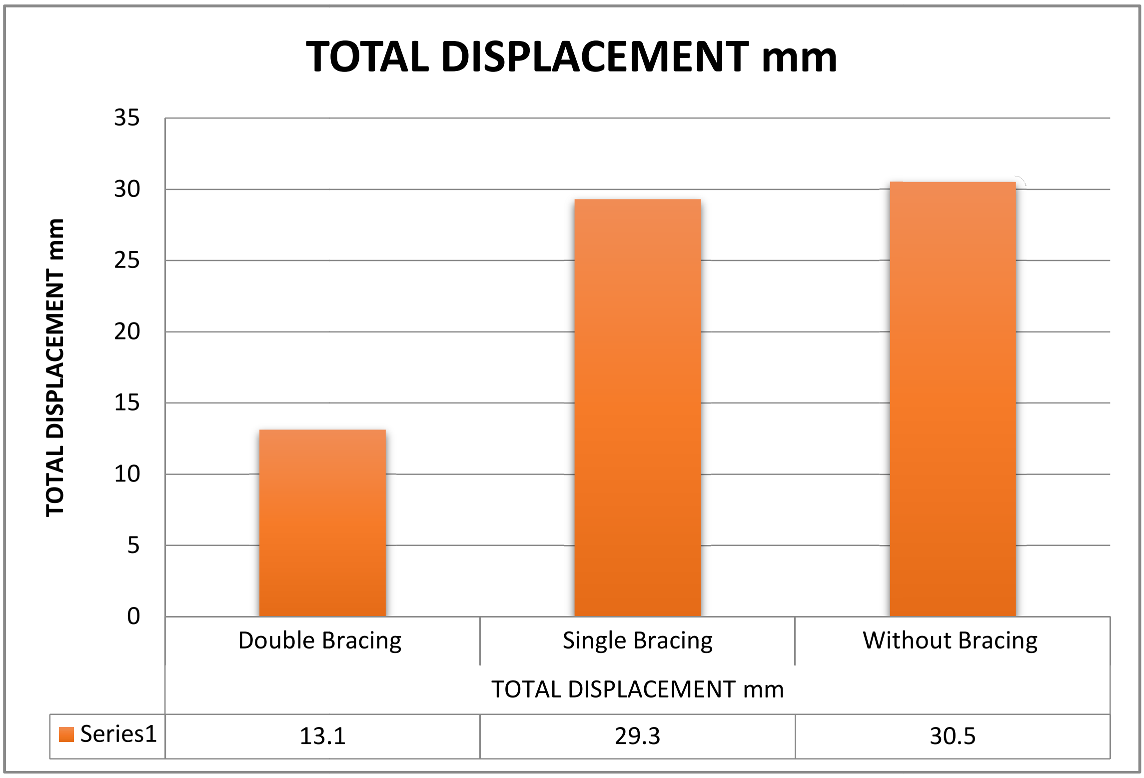


Chart 1 Total Displacement mm

MAX.VELOCITY mm

Table 2 MAX.VELOCITY mm

Max. Velocity mm		
Double Bracing	**Single Bracing**	**Without Bracing**
32.6	43.4	59.6

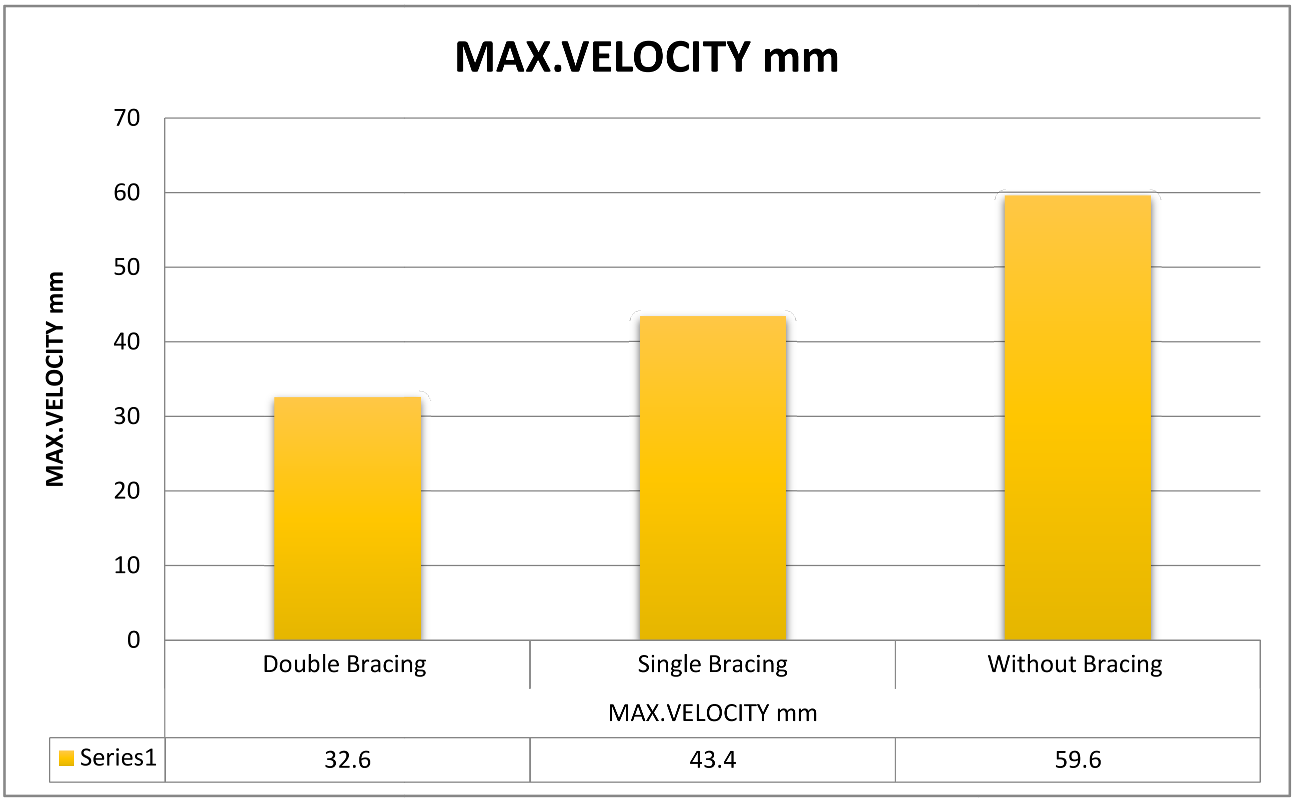


Chart 2 Max. Velocity mm

Max. Acceleration mm

Table 3 Max. Acceleration mm

Max. Acceleration mm		
Double Bracing	**Single Bracing**	**Without Bracing**
283	303	363

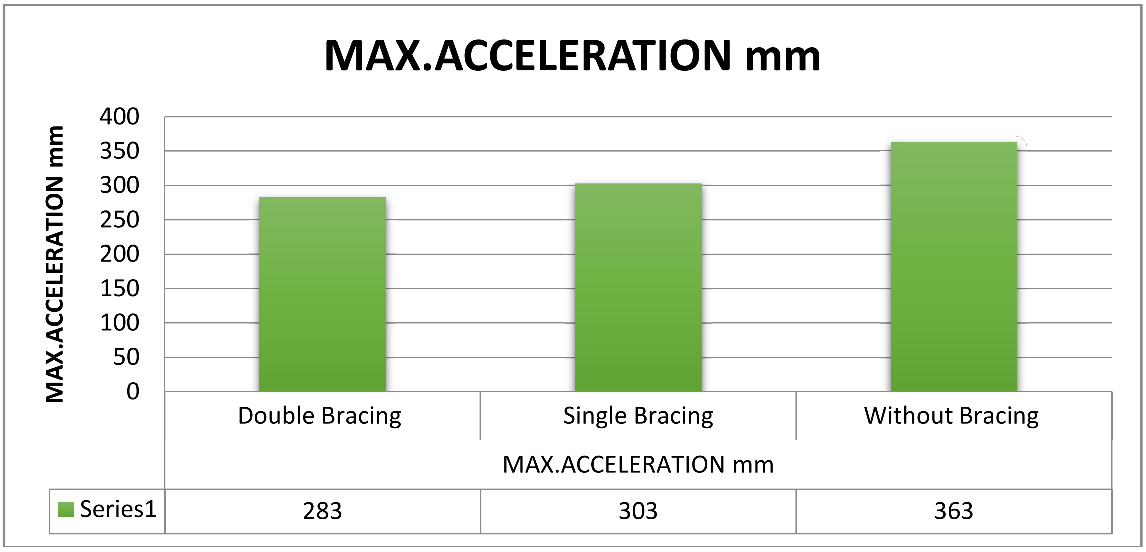


Chart 3 Max. Acceleration mm

V CONCLUSION

From above thesis report following conclusions has been drawn:

All supports recommend framing the connection between the pipe and the pipe rack. We attempted to increase the distance between supports while maintaining the values of stresses and deflection within acceptable limits in this thesis. Supporting beams are spaced at a 6m c/c interval to accommodate pipe with a diameter greater than 12'. As a result, the total number of continuous beam members is lowered on a bigger scale. The objective is to minimise the number of supports in order to minimise the overall cost of erection. To resist lateral deflection and transfer the lateral load through vertical bracings, plan bracings in the K and L shapes are provided. This assists in reducing the size of the members and the project's total cost. Moment connections are considered on transverse bays greater than 9.0 m in length because to the presence of big diameter pipes. Shear connections in the form of vertical bracings are supplied to distribute the shear stress to the base. Each structure has an anchor bay to help minimise forces, which results in a smaller overall size of the member and consequently a lighter overall weight of steel sections. The I or H form of the columns is determined by the moment of inertia. This moment of inertia, in whatever shape it takes, is chosen.

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