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Design and Analysis of Pipe Rack System using STAAD PRO V8i Software

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Abstract: In Industrial Plants like Oil & Gas, Petrochemicals, Refinery etc. Piperacks are most common structures which carries major Pipes with different diameters from one Equipment to another Equipment or from one unit to another unit. Pipe racks are main artery of the Oil & Gas Plants and hence detail planning and study are essential for any industrial projects. As the majority of material involves, there will be cost impact on the project and hence optimization is required. The Pipe racks have to be designed for majority of the loads like primary essential loads and pipe loads .The Analysis of the Pipe rack with suitable loads and with suitable configuration is carried out by using different Software like STAAD Pro, ANSYS, SAP etc. The Members of the Pipe racks has been designed by using Indian Standard, American Standard or British Standard codes as per requirement and location of the project.The Members of the Pipe racks has to be suitable verified for Strength, Vertical and Horizontal Deflection. The overall drift limit of the Pipe racks has to be maintained within the desired limit. A Piperack for the ongoing International project has been Analysed and Design of Super Structure has been carried out by using STAAD Pro software.
Keywords: 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, shear connections and Staad Pro V8i

I. INTRODUCTION

A. General

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.

B. 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) Model and analyze the steel pipe rack using STAAD Pro V8I.
3) Comparison of Manual Method of pipe rack with STAAD Pro V8I.

II. GENERAL ARRANGEMENT VIEWS

The pipe rack model is comprised of 1349 members(1247 beams,16 columns, and 86 bracings(longitudinal,lateral and cross bracings) as shown in figure 2.1.. This Pipe rack is carrying pipes supported at tier elevations TOS(Top Of Steel) at elevation 111.600,TOS(Top Of Steel) at elevation 109.00,TOS(Top Of Steel) at elevation 107.000, TOS(Top Of Steel) at elevation 104.400 .This pipe rack is modelled in STAAD PRO software and all reactions, forces and utility ratios are used for describing thesis.

PIPE RACK PR18-01 is 42m in lengthwise as shown in figure 2.2 This pipe rack is designed and modelled as per the load data given from the mechanical department, from the estimation of the pipe thickness as shown in the figure from 2.2 to figure 2.6 and the load of liquid flowing through pipes given from piping department,from the data given from the vendor and also as per the clients reqirement,clients specification and civil design basis(ASCE 7-02),PIP(2007) PIP STC01015.

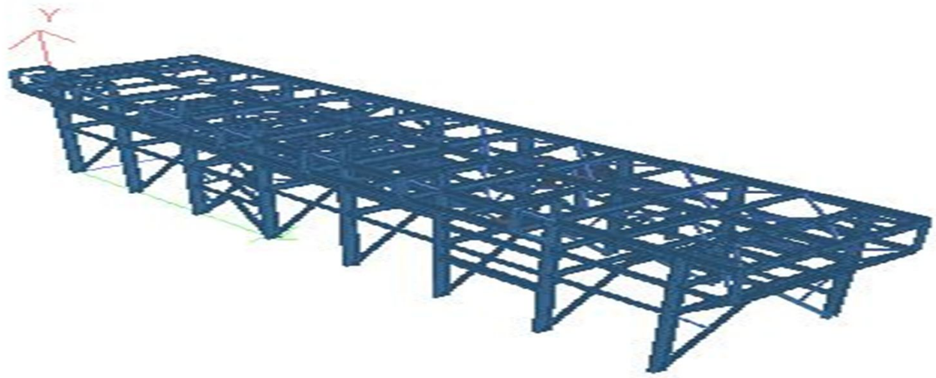

Figure 2.1 PIPE RACK MODEL IN 3D RENDERED VIEW

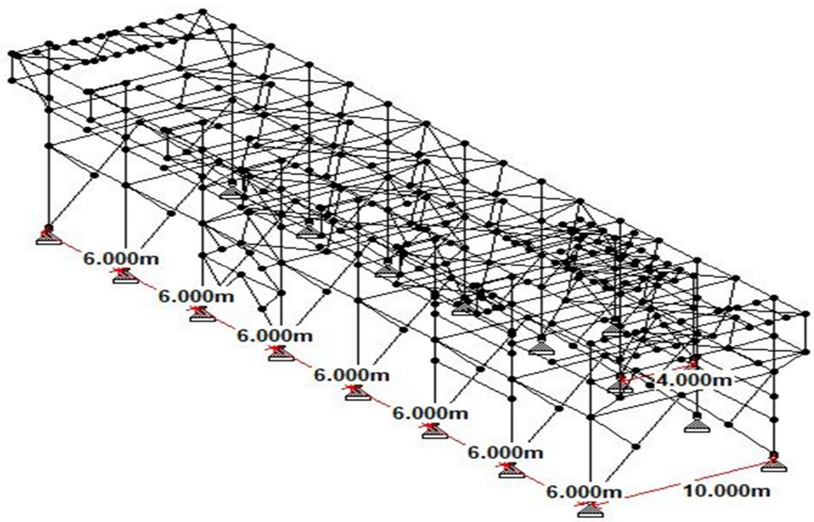

Figure 2.2 view of length of pipe rack and second bay

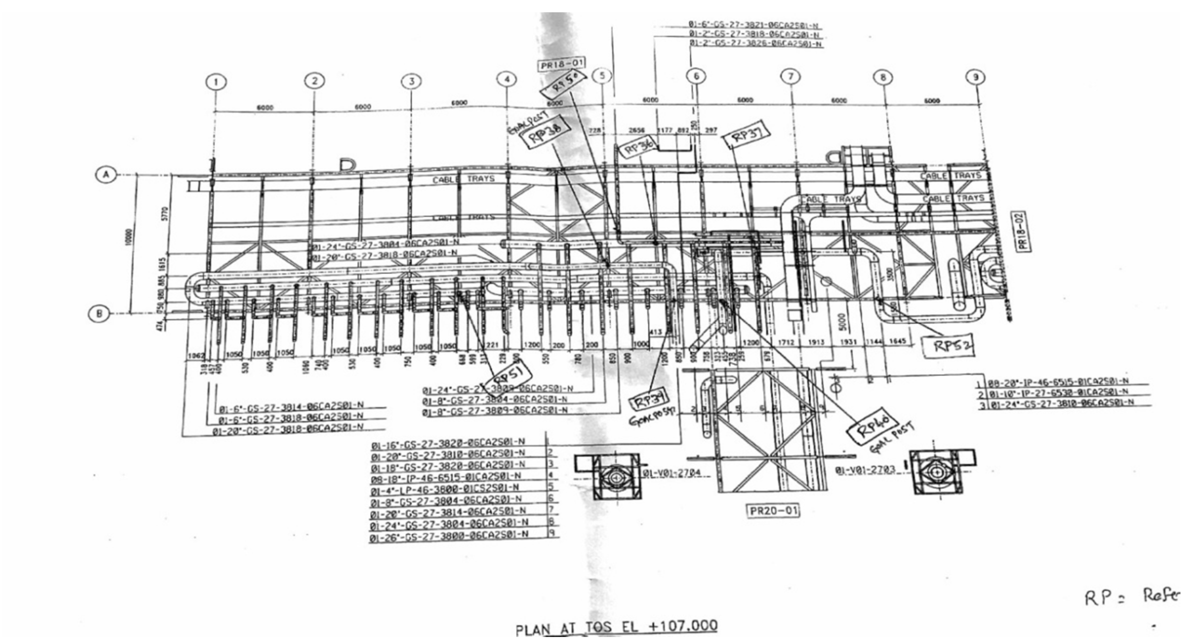

Figure 2.3 Key plan view at level +107.000

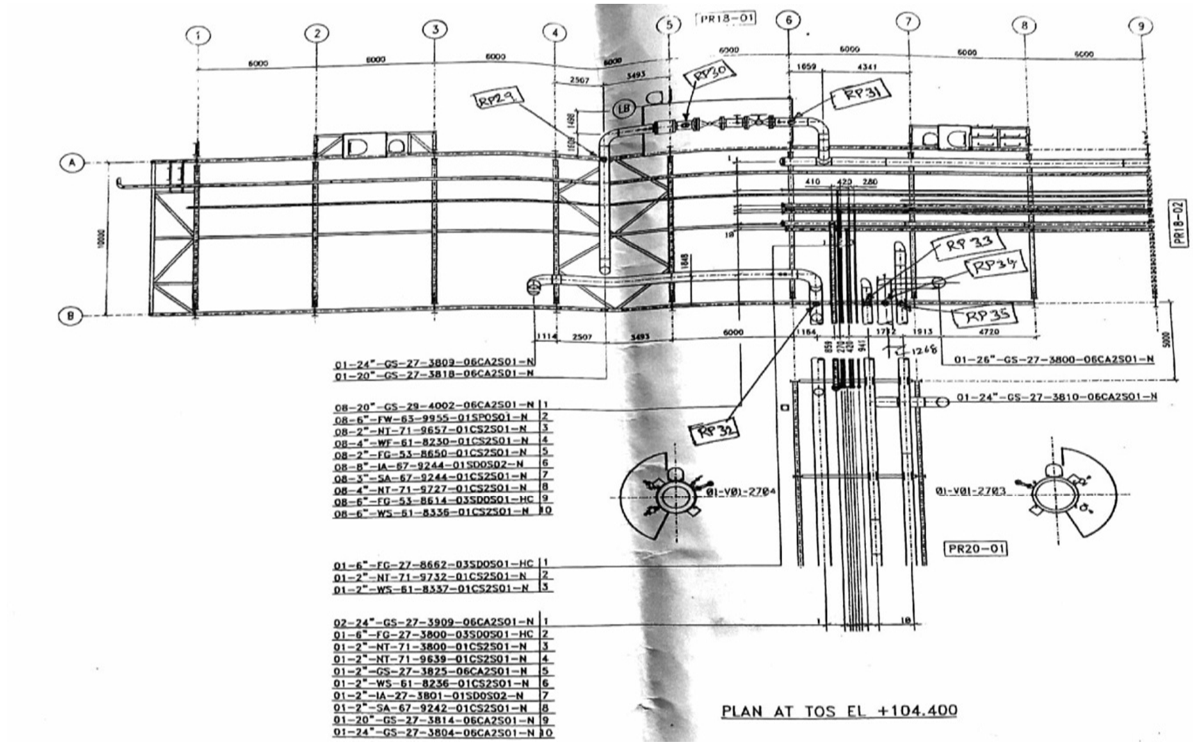

Figure 2.4 Key plan view at level +104.400

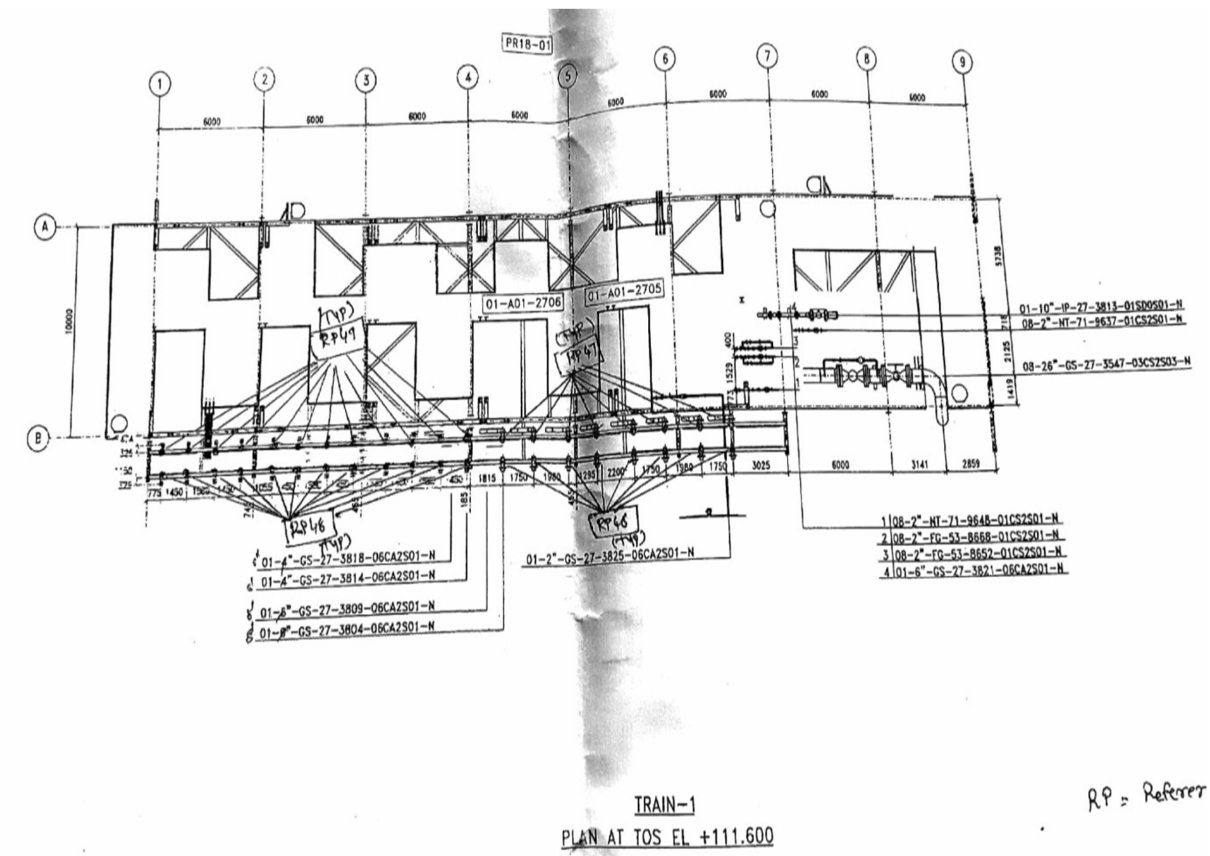

Figure 2.5 Key plan view at level +111.600

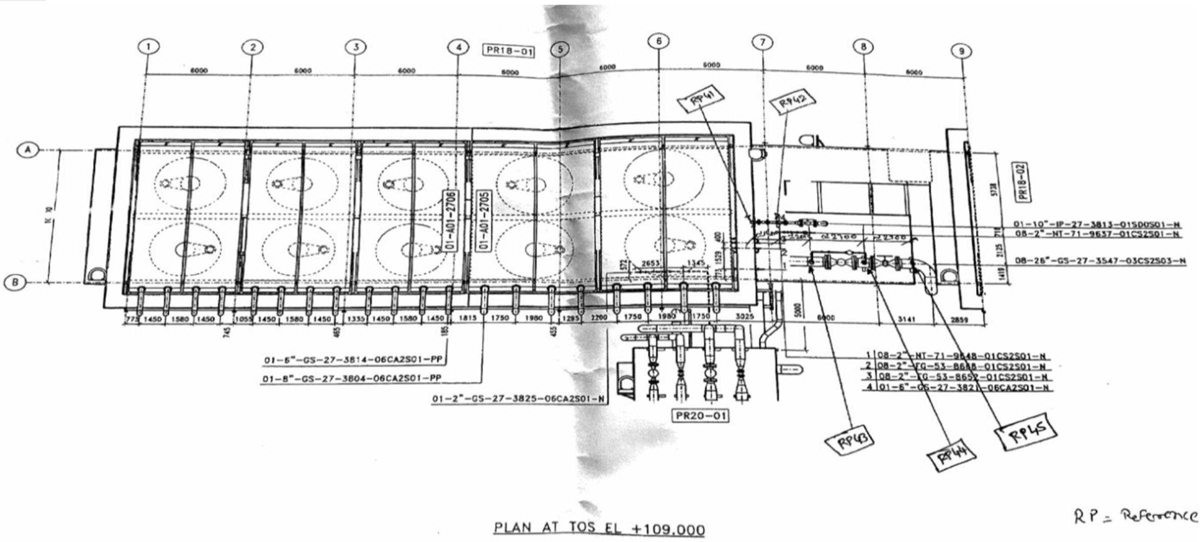

Figure 2.6 Key plan view at level +109.000

There are 8 Grids along the longitudinal direction (Grid-1,Grid-2, Grid-3 Grid-4 Grid-5 Grid-6 Grid-7 Grid-8)in which each grid is separated with a length of 6 meters.So overall length of the pipe rack is 42 meters.
There are two bays along the lateral direction (one bay from Grid-A to Grid-B, and also a carriage way (from Grid-B to Grid-B1).From Grid-A to Grid-B distance between them is 10 meters. And from Grid-B to Grid-B1) the distance is 4 meters.
The analysing and assembling of beams, columns ,bracings(longitudinal, intermediate ,horizontal, plan) has been carried out and the pictures of assembling in STAAD is provided above.

As per the code specifications,

1) The length of each module of the pipe rack should be between 30-42m.So it is taken as 42m pipe rack length.
2) As there are two bays and it is more than one bay in transverse direction transverse column bracing is provided at the first bay and at the bottom tier to top of the base plate.
3) A central longitudinal Tie beam has been provided at the centre as the width of the pipe rack is more than 5m.
4) Plan bracing and vertical bracing are provided as per the requirement in design and also to give clearance for the pipe routing
5) Cable tray supports are provided at 3m as it is maximum spacing.
6) The orientation of the columns is designed and placed as per the maximum moment of inertia.
7) As the width of the pipe rack is more than 4m in both bays. So both the bays are free to access for the human movement below the bottom tiers.
8) The largest pipe diameter 30’’ is passing through Tier-1 Grid-8,the universal beam UB610X305X149 is used to withstand the load.
9) Moment and shear connections are provided as per the design of the column and beam.
10) Vertical bracings are provided between Grid-5 and Grid-6 as the 18”and 24” diameter pipes and cable trays are passing through these grids.

III. DESIGN METHODOLOGY

The design of the pipe rack PR18-01 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.How ever 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.

A. Apipe Rack Geometry

Length of pipe rack		42.00m
Height of first bay		11.60m
Height of second bay		5.95m
Rack main frame spacing		6.00mc/c
Intermediate beam spacing for cable tray level		3m
Width of first bay		10.00m
Width of second bay		4m
FINISHED GROUND LEVEL	ELEVATION	98.20m
Projection of pedestal above FGL		0.25m
U/S of base plate or TOP OF GROUND	ELEVATION	98.45m

PIPE RACK LEVELS	HEIGHT FROM FINISHED GROUND LEVEL	LOADS kN/m^2 Main beams			Remark
		Empty	Content	Hydro	
Level 1	EL +104.40	1.2	0.5	0.5	Pipe tier I
Level 2	EL +107.00	1.2	0.5	0.5	Cable tray + pipe tier IV
Level 3	EL +109.80	1.2	0.5	0.5	Pipe tier III+Access platform

TABLE 4.1 DATA OF PRESSURE ACTING ON PIPES.

B. 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/m^2.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 firehazards shall be taken into account. Fireproofing weights shall be determined based on 34mm thick Fendolite - MII (Unit weight = 7 kN/m^3) applied in the shapeof the steel profile for sizes more than 200mm (in either dimension). For steelprofile 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/m^2 for 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/m^2 for 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 than 12 inch diameter, a uniformly distributed load of 0.6 kN/m^2may 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 thegreater 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.

IV. WIND LOADS ON PIPE RACK

A. Wind on Pipe rack Frames

Wind 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.

B. 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 at 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

C. Thermal Loads On Structure - Tr / Tf

For determining the effect of temperature variations on the exposed pipe rack structure, the temperature variations are computed for summer season and winter season.

The temperature rise in summer TR and the Temperature fall in winter TF shall be calculated.

D. Cable Tray Load – CL

Electrical or Instrument cable load (blanket) shall be 1.00 kN/m^2 per cable tray. Incase the actual loading by Electrical/Instrumentation/Telecom department exceeds the above load, the actual load shall be considered. For vertical drop oftrays along the column locations, uniformly distributed load shall be considered vertically at the respective column locations, for analysis.

E. Snow Load

Snow load shall be ignored for analysis and design of racks.

V. RESULTS AND DISCUSSION

The pipe rack PR18-01 is an international pipe rack project in the Saudi Arabia country. This pipe rack is designed as per the provisions and specifications of the ASCE 7-05 and also PIP(2007)PIP STC01015 and modelled in the STAAD PRO V8i software .The ASCE guideline should be considered as a reference document and not a design guideline.

The STAAD PRO V8i software has analysed this pipe rack in its soft ware in the LRFD method (Load Resistant Factor Design) of AISC 360-10 CODE OF BRITISH PRACTICE.

Various loads have been considered and applied on the structure. The primary loads

As per ASCE 7-05 are

1.Dead Load (DL).

□□Live Load (LL).

□□□Empty Weight of Equipment (EE).

□□□Operating Weight of Piping (EO).

□□□Test Weight of Equipment / Piping (ET).

□□□Temperature load TL(+) & TL(-)

□□□Thermal friction Load (TF).

□□□Thermal Anchor Load (TA).

□□□Wind load (WL)

10.Blanket load.

These loads which are considered world wide in oil and gas and petro chemical industries have been applied on the structure pipe rack PR18-01.The wind load and the stress load has been applied in the structure and in the present thesis which is obtained from the standard organisation of the Saudi Arabia.

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A. Pipe Rack Design

There are 1247 beams,16columns and 86 bracings.All these beams,columns,bracings have
satisfied the allowable and safety requirements of the standard design basis of AISC 360-10 CODE OF BRITISH PRACTICE and the provisions of the PIP(2007)PIP STC01015 piping department.
Various results obtained from the staad model has been provided below in the form of pictures.

B. Model Result For One Column

One of the column result have been given below from the STAAD.PRO CODE CHECKING - (AISC-360-10-LRFD).

Column Number 72 Result

```
                  STAAD.PRO CODE CHECKING - (AISC-360-10-LRFD)   v1.4a
                  ********************************************

ALL UNITS ARE - KN   METE (UNLESS OTHERWISE Noted)

MEMBER     TABLE        RESULT/   CRITICAL COND/      RATIO/      LOADING/
                          FX           MY               MZ        LOCATION
=======================================================================

    72 ST   UB610X305X149            (BRITISH SECTIONS)
                          PASS   Eq. H1-1b             0.256     10001
                     531.38 C          24.81          -55.44        5.95
|-----------------------------------------------------------------------|
| SLENDERNESS                                                           |
| Actual Slenderness Ratio     :     85.000  L/C  :   301               |
| Allowable Slenderness Ratio  :    200.000  LOC  :     0.00            |
|-----------------------------------------------------------------------|
| STRENGTH CHECKS                                                       |
| Critical L/C  :  10001    Ratio      :      0.256(PASS)               |
|          Loc  :     5.95  Condition  :    Eq. H1-1b                   |
|-----------------------------------------------------------------------|
| DESIGN FORCES                                                         |
| Fx:    5.314E+02(C ) Fy:    2.061E+01     Fz:   3.558E+00             |
| Mx:  -2.245E-04     My:    2.481E+01     Mz:  -5.544E+01             |
|-----------------------------------------------------------------------|
| SECTION PROPERTIES   (UNIT:  CM  )                                    |
| Azz:    1.081E+02      Ayy:    7.226E+01     Cw:   8.176E+06          |
| Szz:    4.115E+03      Syy:    6.109E+02                              |
| Izz:    1.260E+05      Iyy:    9.310E+03     Ix:   2.000E+02          |
|-----------------------------------------------------------------------|
| MATERIAL PROPERTIES                                                   |
| Fyld:      265000.000    Fu:      410000.009                          |
|-----------------------------------------------------------------------|
| Actual Member Length:         5.950                                   |
| Design Parameters                                                     |
| Kz:    3.50 Ky:    1.00 NSF:    1.00 SLF:    1.00 CSP:   12.00        |
|-----------------------------------------------------------------------|
| SECTION CLASS    FLANGE /           λ          λP          λr        |
|                  WEB                                                  |
| Compression :  Non-Slender        7.74        N/A        15.76        |
|                Slender           48.56        N/A        41.94        |
| Flexure     :  Compact            7.74      10.70        28.15        |
|                Compact           48.56     105.85       160.46        |
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|-----------------------------------------------------------------------|
| CHECK FOR AXIAL TENSION                                               |
|                                                                       |
|                FORCE     CAPACITY   RATIO     CRITERIA    L/C    LOC  |
| Yield        2.25E+01   4.53E+03   0.005     Eq. D2-1     15    0.00  |
| Rupture      2.25E+01   5.84E+03   0.004     Eq. D2-2     15    0.00  |
|-----------------------------------------------------------------------|
| CHECK FOR AXIAL COMPRESSION                                           |
|                                                                       |
|                FORCE     CAPACITY   RATIO     CRITERIA    L/C    LOC  |
| Maj Buck     5.55E+02   3.19E+03   0.174     Eq. E7-1    215    0.00  |
| Min Buck     5.55E+02   3.08E+03   0.180     Eq. E7-1    215    0.00  |
| Flexural                                                              |
| Tor Buck     5.55E+02   3.56E+03   0.156     Eq. E7-1    215    0.00  |
| Intermediate                                                          |
| Results         Ag        KL/r       Fcr        Fe         Pn         |
| Maj Buck     1.90E-02    80.87   1.87E+05   3.17E+05   3.55E+03       |
| Min Buck     1.90E-02    85.00   1.80E+05   2.87E+05   3.42E+03       |
| Flexural        Ag        Fcr        Pn                               |
| Tor Buck     1.88E-02   2.08E+05   3.95E+03                           |
|-----------------------------------------------------------------------|
| CHECK FOR SHEAR                                                       |
|                                                                       |
|                FORCE     CAPACITY   RATIO     CRITERIA    L/C    LOC  |
| Major       -5.80E+00   1.55E+03   0.004     Eq. G2-1     16    5.95  |
| Minor       -2.92E+01   1.15E+03   0.025     Eq. G2-1    209    0.00  |
| Intermediate                                                          |
| Results         Aw         Cv        Kv       h/tw       Vn           |
| Major        1.08E-02     1.00      1.20      7.74   1.72E+03         |
| Minor        7.23E-03     1.00      0.00     48.56   1.15E+03         |
|-----------------------------------------------------------------------|
| CHECK FOR BENDING-YIELDING                                            |
|                                                                       |
|                FORCE     CAPACITY   RATIO     CRITERIA    L/C    LOC  |
| Major       -9.69E+01   1.09E+03   0.089     Eq. F2-1    209    5.95  |
| Minor        2.48E+01   2.23E+02   0.111     Eq. F6-1  10001    5.95  |
| Intermediate    Mn         My                                         |
| Major        1.22E+03   0.00E+00                                      |
| Minor        2.48E+02   0.00E+00                                      |
|-----------------------------------------------------------------------|
| CHECK FOR BENDING-LATERAL TORSIONAL BUCKLING                          |
|                                                                       |
|                FORCE     CAPACITY   RATIO     CRITERIA    L/C    LOC  |
| Major       -9.69E+01   9.47E+02   0.102     Eq. F2-2    209    5.95  |
| Intermediate    Mn         Me        Cb       Lp        Lr       Lb   |
| Major        1.05E+03   0.00E+00   1.00     3.47     10.32     5.95   |
```

ALL UNITS ARE - KN METE (UNLESS OTHERWISE Noted)

```
|-----------------------------------------------------------------------|
| CHECK FOR FLEXURE TENS/COMP INTERACTION                               |
|                    RATIO      CRITERIA     L/C      LOC               |
| Flexure Comp       0.256      Eq. H1-1b  10001      5.95              |
| Flexure Tens       0.170      Eq. H1-1b  10001      5.95              |
| Intermediate      Mcx /       Mrx /       Pc /                        |
|                   Mcy         Mry         Pr                          |
| Flexure Comp      9.47E+02    5.54E+01    3.08E+03                    |
|                   2.23E+02    2.48E+01    5.31E+02                    |
| Flexure Tens      9.47E+02    5.54E+01    4.53E+03                    |
|                   2.23E+02    2.48E+01    0.00E+00                    |
|-----------------------------------------------------------------------|
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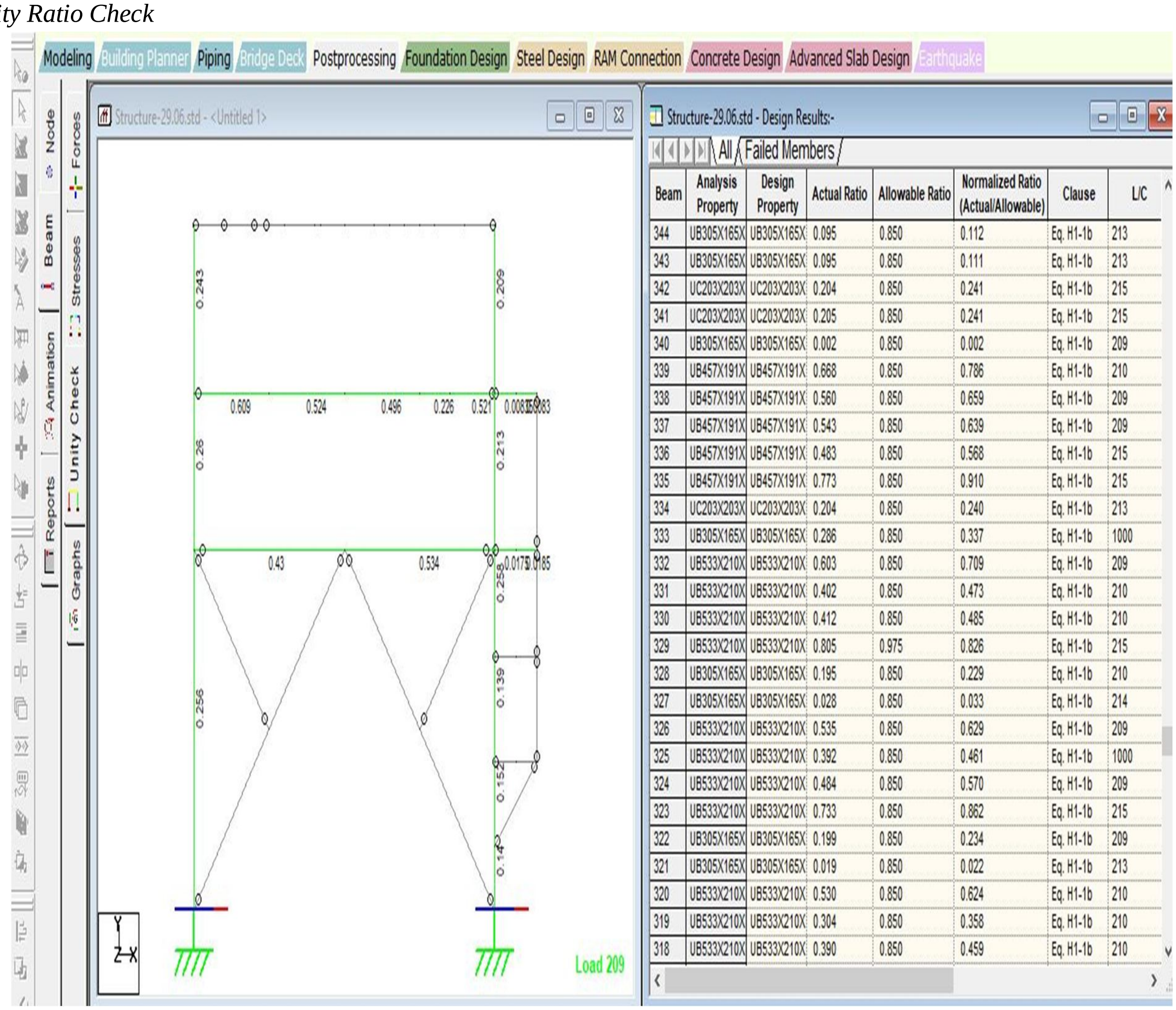
Sway Deflection Check

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	Mm	rX rad	rY rad	rZ rad
388	301 COMBINATION LOAD CASE 6	6.223	-0.372	0.252	6.239	0	0	0
417	301 COMBINATION LOAD CASE 6	6.11	-0.47	0.316	6.136	0	0	0
451	301 COMBINATION LOAD CASE 6	5.575	-0.505	0.375	5.61	0	0	0
486	301 COMBINATION LOAD CASE 6	4.999	-0.407	0.41	5.032	0	0	0

Height of pipe rack = 5950mm
Allowable deflection = H/325=18.30769mm As per Indian code criteria
Actual deflection = 6.223mm<18.30769mm
SO SAFE IN DEFLECTION.

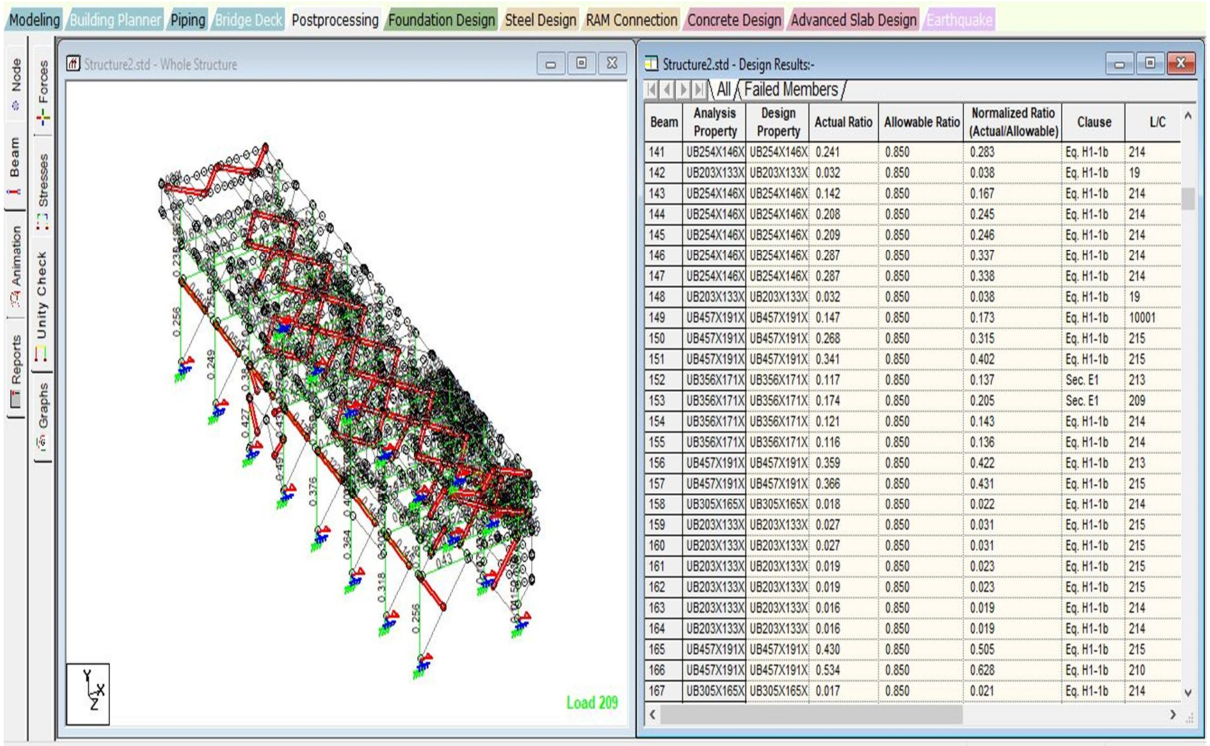
1) *Utility Ratio Check*



Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
344	UB305X165X	UB305X165X	0.095	0.850	0.112	Eq. H1-1b	213
343	UB305X165X	UB305X165X	0.095	0.850	0.111	Eq. H1-1b	213
342	UC203X203X	UC203X203X	0.204	0.850	0.241	Eq. H1-1b	215
341	UC203X203X	UC203X203X	0.205	0.850	0.241	Eq. H1-1b	215
340	UB305X165X	UB305X165X	0.002	0.850	0.002	Eq. H1-1b	209
339	UB457X191X	UB457X191X	0.668	0.850	0.786	Eq. H1-1b	210
338	UB457X191X	UB457X191X	0.560	0.850	0.659	Eq. H1-1b	209
337	UB457X191X	UB457X191X	0.543	0.850	0.639	Eq. H1-1b	209
336	UB457X191X	UB457X191X	0.483	0.850	0.568	Eq. H1-1b	215
335	UB457X191X	UB457X191X	0.773	0.850	0.910	Eq. H1-1b	215
334	UC203X203X	UC203X203X	0.204	0.850	0.240	Eq. H1-1b	213
333	UB305X165X	UB305X165X	0.286	0.850	0.337	Eq. H1-1b	1000
332	UB533X210X	UB533X210X	0.603	0.850	0.709	Eq. H1-1b	209
331	UB533X210X	UB533X210X	0.402	0.850	0.473	Eq. H1-1b	210
330	UB533X210X	UB533X210X	0.412	0.850	0.485	Eq. H1-1b	210
329	UB533X210X	UB533X210X	0.805	0.975	0.826	Eq. H1-1b	215
328	UB305X165X	UB305X165X	0.195	0.850	0.229	Eq. H1-1b	210
327	UB305X165X	UB305X165X	0.028	0.850	0.033	Eq. H1-1b	214
326	UB533X210X	UB533X210X	0.535	0.850	0.629	Eq. H1-1b	209
325	UB533X210X	UB533X210X	0.392	0.850	0.461	Eq. H1-1b	1000
324	UB533X210X	UB533X210X	0.484	0.850	0.570	Eq. H1-1b	209
323	UB533X210X	UB533X210X	0.733	0.850	0.862	Eq. H1-1b	215
322	UB305X165X	UB305X165X	0.199	0.850	0.234	Eq. H1-1b	209
321	UB305X165X	UB305X165X	0.019	0.850	0.022	Eq. H1-1b	213
320	UB533X210X	UB533X210X	0.530	0.850	0.624	Eq. H1-1b	210
319	UB533X210X	UB533X210X	0.304	0.850	0.358	Eq. H1-1b	210
318	UB533X210X	UB533X210X	0.390	0.850	0.459	Eq. H1-1b	210

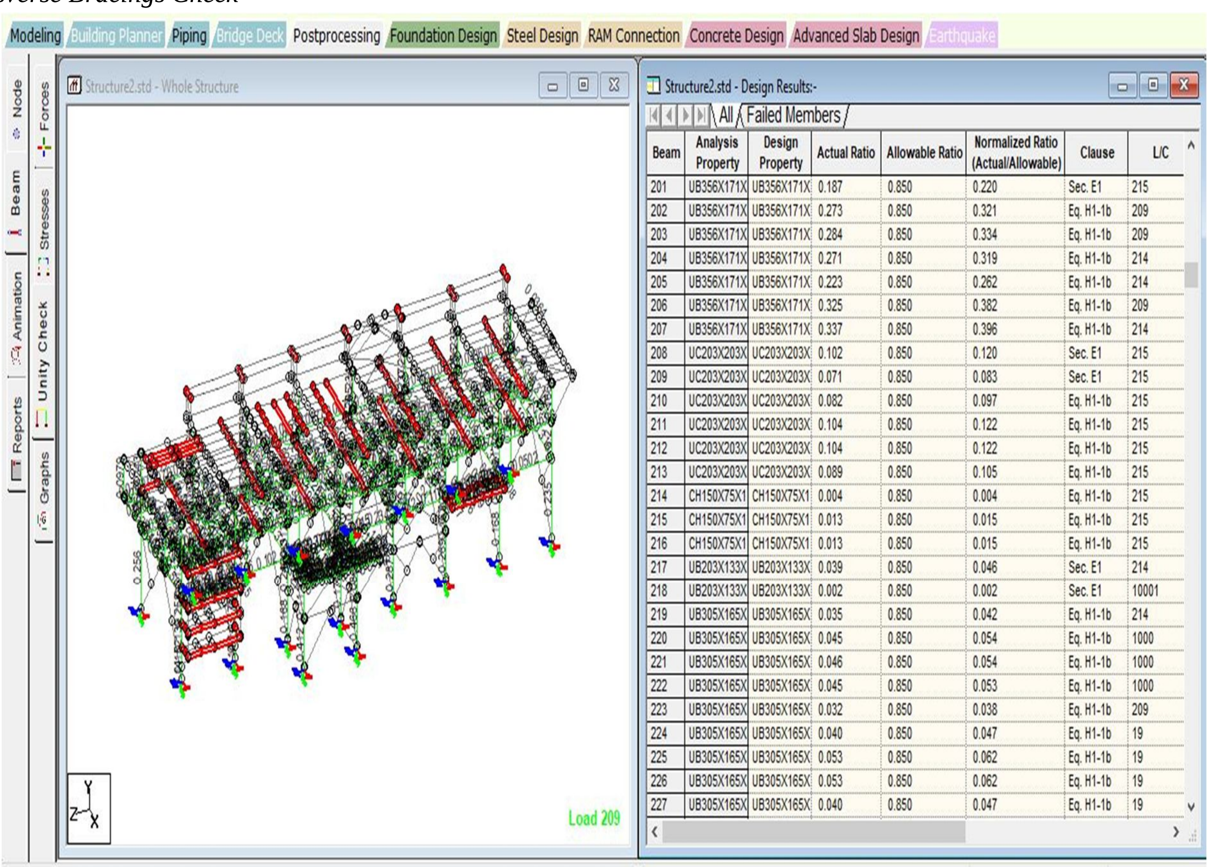
All utility Ratio checks are less than the allowable ratios so the beams and columns are safe in utility ratio.

2) Plan Bracings Check



Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
141	UB254X146X	UB254X146X	0.241	0.850	0.283	Eq. H1-1b	214
142	UB203X133X	UB203X133X	0.032	0.850	0.038	Eq. H1-1b	19
143	UB254X146X	UB254X146X	0.142	0.850	0.167	Eq. H1-1b	214
144	UB254X146X	UB254X146X	0.208	0.850	0.245	Eq. H1-1b	214
145	UB254X146X	UB254X146X	0.209	0.850	0.246	Eq. H1-1b	214
146	UB254X146X	UB254X146X	0.287	0.850	0.337	Eq. H1-1b	214
147	UB254X146X	UB254X146X	0.287	0.850	0.338	Eq. H1-1b	214
148	UB203X133X	UB203X133X	0.032	0.850	0.038	Eq. H1-1b	19
149	UB457X191X	UB457X191X	0.147	0.850	0.173	Eq. H1-1b	10001
150	UB457X191X	UB457X191X	0.268	0.850	0.315	Eq. H1-1b	215
151	UB457X191X	UB457X191X	0.341	0.850	0.402	Eq. H1-1b	215
152	UB356X171X	UB356X171X	0.117	0.850	0.137	Sec. E1	213
153	UB356X171X	UB356X171X	0.174	0.850	0.205	Sec. E1	209
154	UB356X171X	UB356X171X	0.121	0.850	0.143	Eq. H1-1b	214
155	UB356X171X	UB356X171X	0.116	0.850	0.136	Eq. H1-1b	214
156	UB457X191X	UB457X191X	0.359	0.850	0.422	Eq. H1-1b	213
157	UB457X191X	UB457X191X	0.366	0.850	0.431	Eq. H1-1b	215
158	UB305X165X	UB305X165X	0.018	0.850	0.022	Eq. H1-1b	214
159	UB203X133X	UB203X133X	0.027	0.850	0.031	Eq. H1-1b	215
160	UB203X133X	UB203X133X	0.027	0.850	0.031	Eq. H1-1b	215
161	UB203X133X	UB203X133X	0.019	0.850	0.023	Eq. H1-1b	215
162	UB203X133X	UB203X133X	0.019	0.850	0.023	Eq. H1-1b	215
163	UB203X133X	UB203X133X	0.016	0.850	0.019	Eq. H1-1b	214
164	UB203X133X	UB203X133X	0.016	0.850	0.019	Eq. H1-1b	214
165	UB457X191X	UB457X191X	0.430	0.850	0.505	Eq. H1-1b	215
166	UB457X191X	UB457X191X	0.534	0.850	0.628	Eq. H1-1b	210
167	UB305X165X	UB305X165X	0.017	0.850	0.021	Eq. H1-1b	214

3) Transverse Bracings Check



Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
201	UB356X171X	UB356X171X	0.187	0.850	0.220	Sec. E1	215
202	UB356X171X	UB356X171X	0.273	0.850	0.321	Eq. H1-1b	209
203	UB356X171X	UB356X171X	0.284	0.850	0.334	Eq. H1-1b	209
204	UB356X171X	UB356X171X	0.271	0.850	0.319	Eq. H1-1b	214
205	UB356X171X	UB356X171X	0.223	0.850	0.262	Eq. H1-1b	214
206	UB356X171X	UB356X171X	0.325	0.850	0.382	Eq. H1-1b	209
207	UB356X171X	UB356X171X	0.337	0.850	0.396	Eq. H1-1b	214
208	UC203X203X	UC203X203X	0.102	0.850	0.120	Sec. E1	215
209	UC203X203X	UC203X203X	0.071	0.850	0.083	Sec. E1	215
210	UC203X203X	UC203X203X	0.082	0.850	0.097	Eq. H1-1b	215
211	UC203X203X	UC203X203X	0.104	0.850	0.122	Eq. H1-1b	215
212	UC203X203X	UC203X203X	0.104	0.850	0.122	Eq. H1-1b	215
213	UC203X203X	UC203X203X	0.089	0.850	0.105	Eq. H1-1b	215
214	CH150X75X1	CH150X75X1	0.004	0.850	0.004	Eq. H1-1b	215
215	CH150X75X1	CH150X75X1	0.013	0.850	0.015	Eq. H1-1b	215
216	CH150X75X1	CH150X75X1	0.013	0.850	0.015	Eq. H1-1b	215
217	UB203X133X	UB203X133X	0.039	0.850	0.046	Sec. E1	214
218	UB203X133X	UB203X133X	0.002	0.850	0.002	Sec. E1	10001
219	UB305X165X	UB305X165X	0.035	0.850	0.042	Eq. H1-1b	214
220	UB305X165X	UB305X165X	0.045	0.850	0.054	Eq. H1-1b	1000
221	UB305X165X	UB305X165X	0.046	0.850	0.054	Eq. H1-1b	1000
222	UB305X165X	UB305X165X	0.045	0.850	0.053	Eq. H1-1b	1000
223	UB305X165X	UB305X165X	0.032	0.850	0.038	Eq. H1-1b	209
224	UB305X165X	UB305X165X	0.040	0.850	0.047	Eq. H1-1b	19
225	UB305X165X	UB305X165X	0.053	0.850	0.062	Eq. H1-1b	19
226	UB305X165X	UB305X165X	0.053	0.850	0.062	Eq. H1-1b	19
227	UB305X165X	UB305X165X	0.040	0.850	0.047	Eq. H1-1b	19

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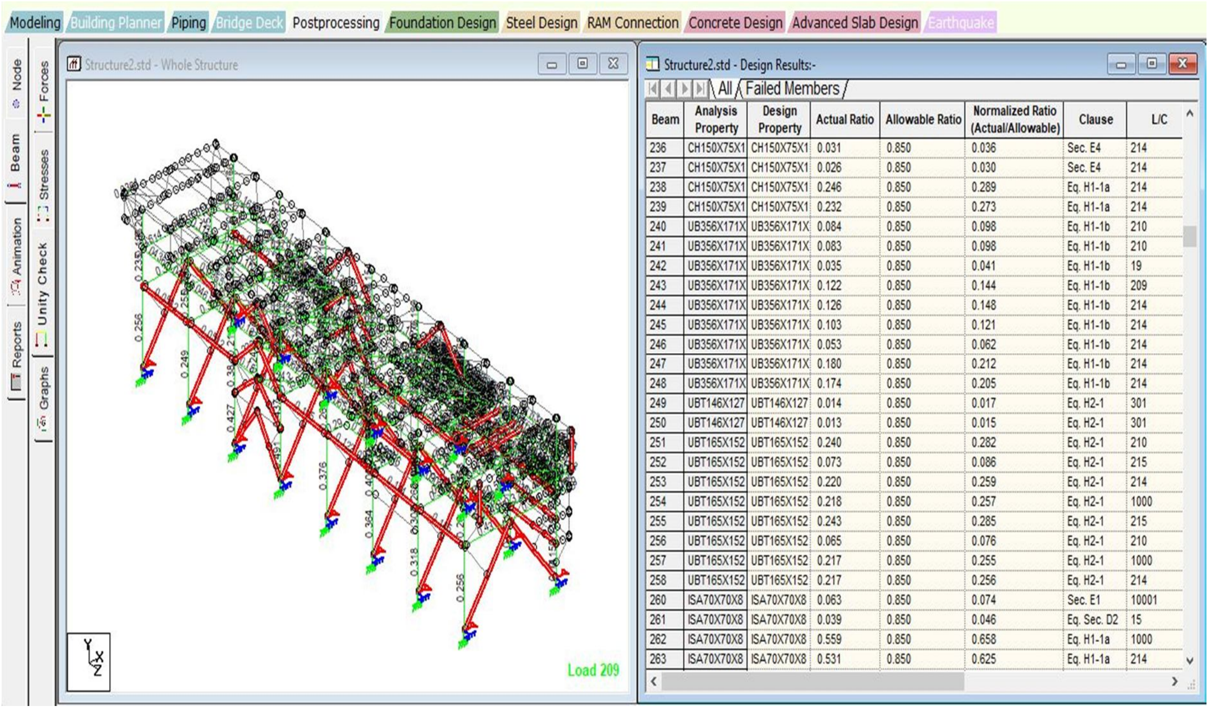
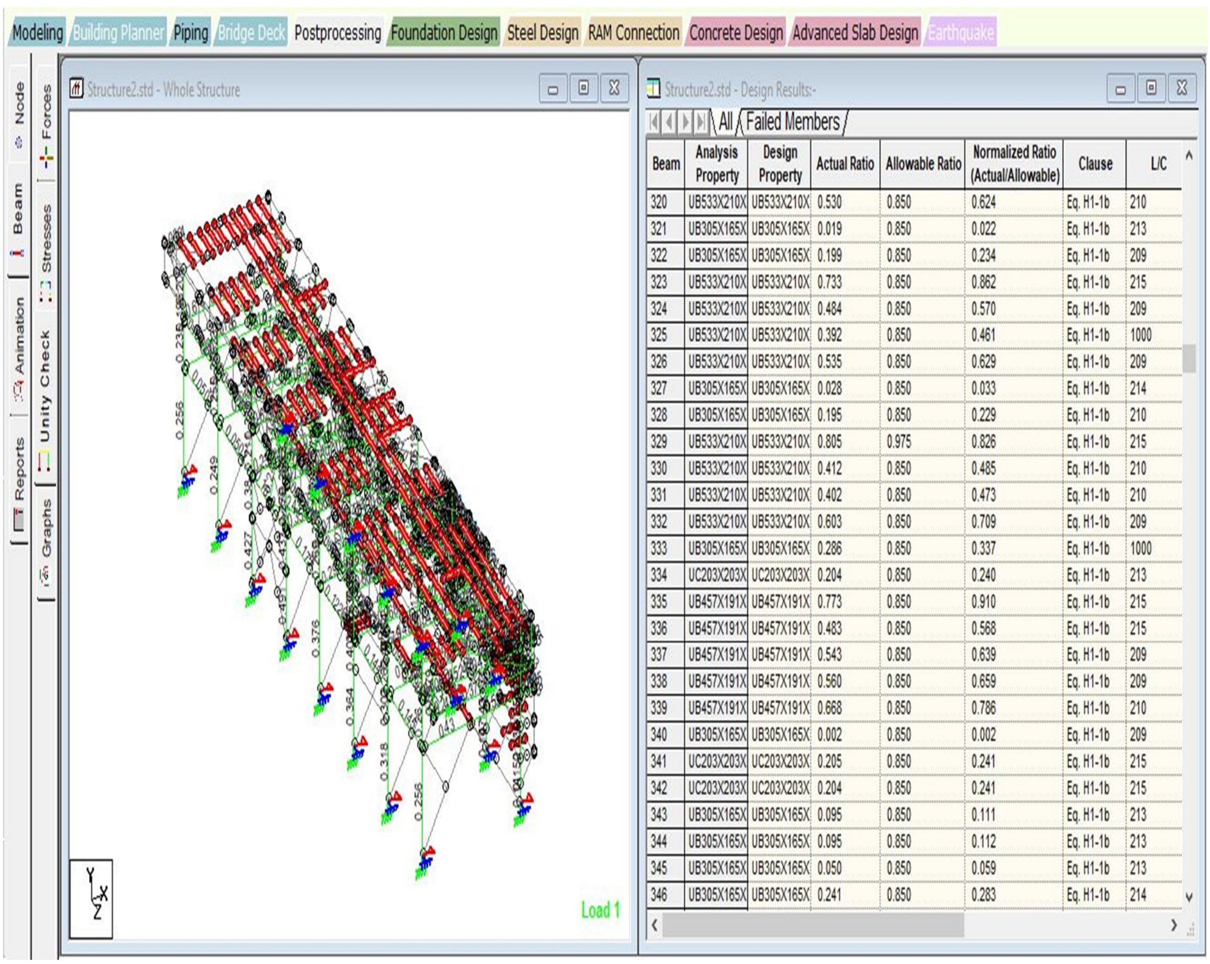
4) Longitudinal Bracings Check



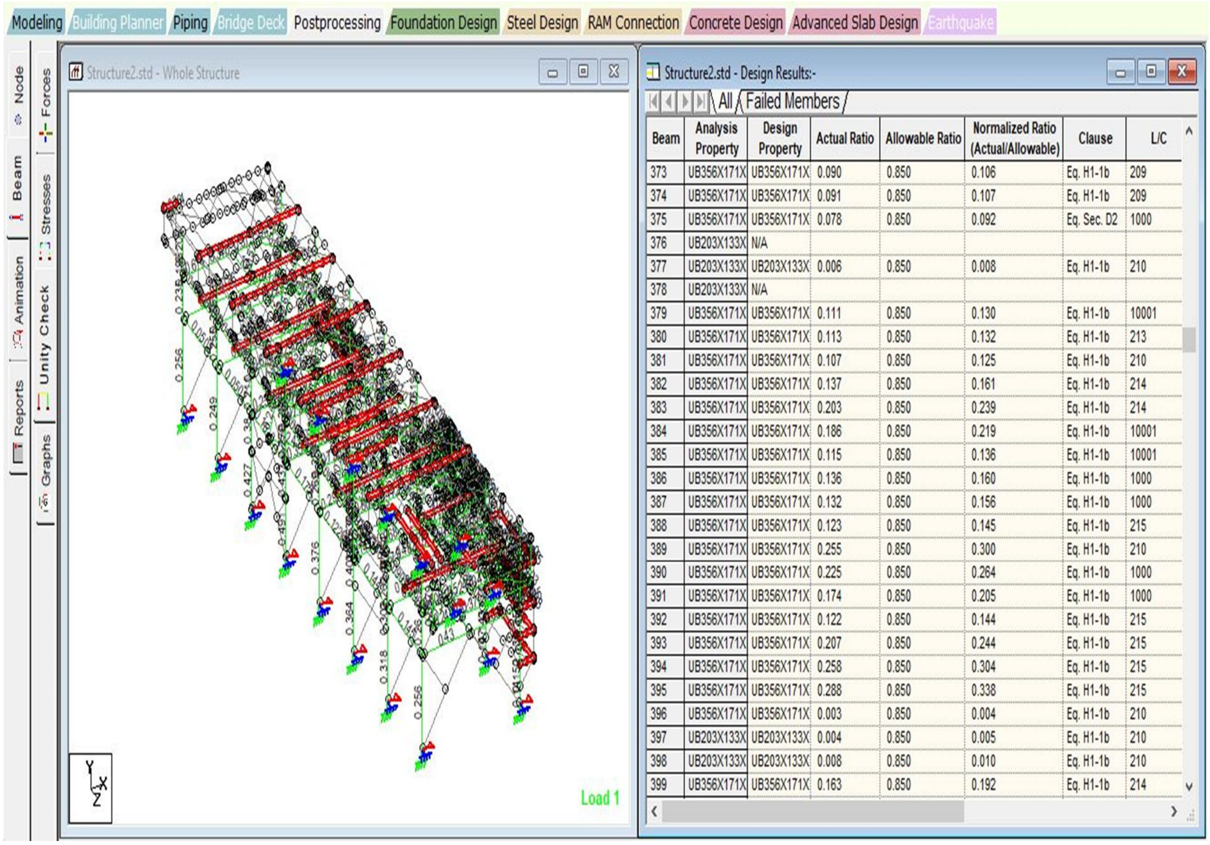
Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
236	CH150X75X1	CH150X75X1	0.031	0.850	0.036	Sec. E4	214
237	CH150X75X1	CH150X75X1	0.026	0.850	0.030	Sec. E4	214
238	CH150X75X1	CH150X75X1	0.246	0.850	0.289	Eq. H1-1a	214
239	CH150X75X1	CH150X75X1	0.232	0.850	0.273	Eq. H1-1a	214
240	UB356X171X	UB356X171X	0.084	0.850	0.098	Eq. H1-1b	210
241	UB356X171X	UB356X171X	0.083	0.850	0.098	Eq. H1-1b	210
242	UB356X171X	UB356X171X	0.035	0.850	0.041	Eq. H1-1b	19
243	UB356X171X	UB356X171X	0.122	0.850	0.144	Eq. H1-1b	209
244	UB356X171X	UB356X171X	0.126	0.850	0.148	Eq. H1-1b	214
245	UB356X171X	UB356X171X	0.103	0.850	0.121	Eq. H1-1b	214
246	UB356X171X	UB356X171X	0.053	0.850	0.062	Eq. H1-1b	214
247	UB356X171X	UB356X171X	0.180	0.850	0.212	Eq. H1-1b	214
248	UB356X171X	UB356X171X	0.174	0.850	0.205	Eq. H1-1b	214
249	UBT146X127	UBT146X127	0.014	0.850	0.017	Eq. H2-1	301
250	UBT146X127	UBT146X127	0.013	0.850	0.015	Eq. H2-1	301
251	UBT165X152	UBT165X152	0.240	0.850	0.282	Eq. H2-1	210
252	UBT165X152	UBT165X152	0.073	0.850	0.086	Eq. H2-1	215
253	UBT165X152	UBT165X152	0.220	0.850	0.259	Eq. H2-1	214
254	UBT165X152	UBT165X152	0.218	0.850	0.257	Eq. H2-1	1000
255	UBT165X152	UBT165X152	0.243	0.850	0.285	Eq. H2-1	215
256	UBT165X152	UBT165X152	0.065	0.850	0.076	Eq. H2-1	210
257	UBT165X152	UBT165X152	0.217	0.850	0.255	Eq. H2-1	1000
258	UBT165X152	UBT165X152	0.217	0.850	0.256	Eq. H2-1	214
260	ISA70X70X8	ISA70X70X8	0.063	0.850	0.074	Sec. E1	10001
261	ISA70X70X8	ISA70X70X8	0.039	0.850	0.046	Eq. Sec. D2	15
262	ISA70X70X8	ISA70X70X8	0.559	0.850	0.658	Eq. H1-1a	1000
263	ISA70X70X8	ISA70X70X8	0.531	0.850	0.625	Eq. H1-1a	214

5) Transverse Beams Check

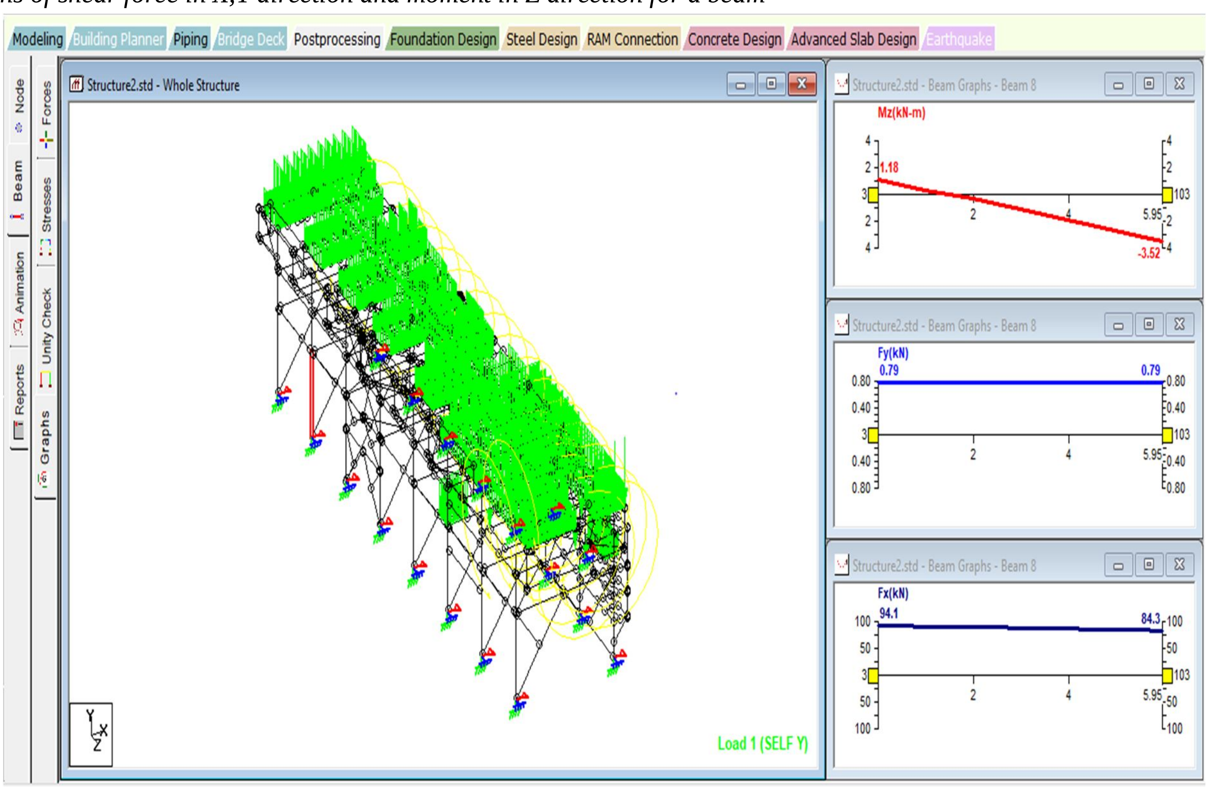


Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
320	UB533X210X	UB533X210X	0.530	0.850	0.624	Eq. H1-1b	210
321	UB305X165X	UB305X165X	0.019	0.850	0.022	Eq. H1-1b	213
322	UB305X165X	UB305X165X	0.199	0.850	0.234	Eq. H1-1b	209
323	UB533X210X	UB533X210X	0.733	0.850	0.862	Eq. H1-1b	215
324	UB533X210X	UB533X210X	0.484	0.850	0.570	Eq. H1-1b	209
325	UB533X210X	UB533X210X	0.392	0.850	0.461	Eq. H1-1b	1000
326	UB533X210X	UB533X210X	0.535	0.850	0.629	Eq. H1-1b	209
327	UB305X165X	UB305X165X	0.028	0.850	0.033	Eq. H1-1b	214
328	UB305X165X	UB305X165X	0.195	0.850	0.229	Eq. H1-1b	210
329	UB533X210X	UB533X210X	0.805	0.975	0.826	Eq. H1-1b	215
330	UB533X210X	UB533X210X	0.412	0.850	0.485	Eq. H1-1b	210
331	UB533X210X	UB533X210X	0.402	0.850	0.473	Eq. H1-1b	210
332	UB533X210X	UB533X210X	0.603	0.850	0.709	Eq. H1-1b	209
333	UB305X165X	UB305X165X	0.286	0.850	0.337	Eq. H1-1b	1000
334	UC203X203X	UC203X203X	0.204	0.850	0.240	Eq. H1-1b	213
335	UB457X191X	UB457X191X	0.773	0.850	0.910	Eq. H1-1b	215
336	UB457X191X	UB457X191X	0.483	0.850	0.568	Eq. H1-1b	215
337	UB457X191X	UB457X191X	0.543	0.850	0.639	Eq. H1-1b	209
338	UB457X191X	UB457X191X	0.560	0.850	0.659	Eq. H1-1b	209
339	UB457X191X	UB457X191X	0.668	0.850	0.786	Eq. H1-1b	210
340	UB305X165X	UB305X165X	0.002	0.850	0.002	Eq. H1-1b	209
341	UC203X203X	UC203X203X	0.205	0.850	0.241	Eq. H1-1b	215
342	UC203X203X	UC203X203X	0.204	0.850	0.241	Eq. H1-1b	215
343	UB305X165X	UB305X165X	0.095	0.850	0.111	Eq. H1-1b	213
344	UB305X165X	UB305X165X	0.095	0.850	0.112	Eq. H1-1b	213
345	UB305X165X	UB305X165X	0.050	0.850	0.059	Eq. H1-1b	213
346	UB305X165X	UB305X165X	0.241	0.850	0.283	Eq. H1-1b	214

6) Longitudinal Beams Check



7) Graphs of shear force in X,Y direction and moment in Z direction for a beam



VI. DISCUSSION ON RESULTS

1) In this pipe rack model design parameters has been applied in staad model under two different sections namely, Strength Design & Serviceability.
2) To control the lateral moments the fixed but support is provided i.e,fixed in one direction and pinned in another direction.
3) The STAAD PRO V8i software analyses in the LRFD method so the result can be checked as per the strength.
4) The strength can generally be checked based on the UTILITY RATIO,DEFLECTION
5) According to the column result provided in 6.3.1 the strength ratio is 0.256 which is less than 1 as per AISC 360-10 So the strength check is safe for this structure.
6) Slenderness ratio allowable is 200.00 an our actual obtained slenderness ratio is 83.000 so safe in slenderness ratio
7) Design parameter KZ is 1.00 for columns. allowable as per code is 1.2.
8) For the deflection check:- Height of pipe rack = 5950mm Allowable deflection = H/325=18.30769mm As per Indian code criteria Actual deflection = 6.223mm<18.30769mm.SO SAFE IN DEFLECTION.
9) All the utility ratios checked in 6.3.3 are less than the allowable ratios
10) Plan bracings, longitudinal beams, transverse bracings, longitudinal bracings checks provided as in 6.3.4.6.3.5,6.3.6,6.3.7 are all less than the allowable ratios.
11) Central longitudinal Tie beam has been provided at the centre as the width of the pipe rack is more than 5m as per code specifications.
12) Plan bracing and vertical bracing are provided as per the requirement in design and also to give clearance for the pipe routing.
13) The orientation of the columns is designed and placed as per the maximum moment of inertia.
14) As the width of the pipe rack is more than 4m in both bays. So both the bays are free to access for the human movement below the bottom tiers.
15) So the design and analysis has been followed as per the codes AISC 360-10 and PIP(2007)PIP STC01015 piping department and also as per the clent requirement. So based on the above results we can see that the structure is safe.

VII. CONCLUSIONS

1) The pipe rack steel structure PR 18-01 has been modelled and analysed using **LRFD**(**load resistant factor design**) method in American code AISC 360-10 CODE in STAAD PRO V8i software.
2) The tonnage of the whole structure was 1365.068 TONNES.
3) The orientation of the columns as I shape and H shape depends on the Moment of inertia.This moment of inertia in which shape it is more, then that shape is opted.
4) All the bracings are provided as per project requirements.
5) Plan bracings are provided so as to resist the lateral deflection.also to transfer wind force,longitudinal forces to braced bay. The shape of the plan bracings in this project are Rhombus shaped, L shaped.
6) This plan bracing shapes mainly helps to reduce the size of the structure and also to reduce the overall cost.
7) As the wind load and moment is there in the lateral direction so,we opted for fixed but support. This support is fixed in one direction(x) and pinned in one direction(z).
8) Shear connections are provided as vertical bracings to carry the shear force to the base plates.
9) Moment connections are provided on the plan bracing and transverse bays where the pipe with larger diameters are rested on this beams.
10) Expansion loop is provided for every 6m so as to control thermal stresses.(temperature load rise,temperature load fall) as per code specifications).
11) Deflection was found to be under control (Allowable deflection=H/325=18.30679m, Actual deflection=6.223m).
12) The load data for the foundation design is generated and is provided in the results (output).
13) Typical single column member has been added in the result.
14) The governing case for the load combination is DEAD LOAD+WIND LOAD+PIPE OPERATING LOAD.

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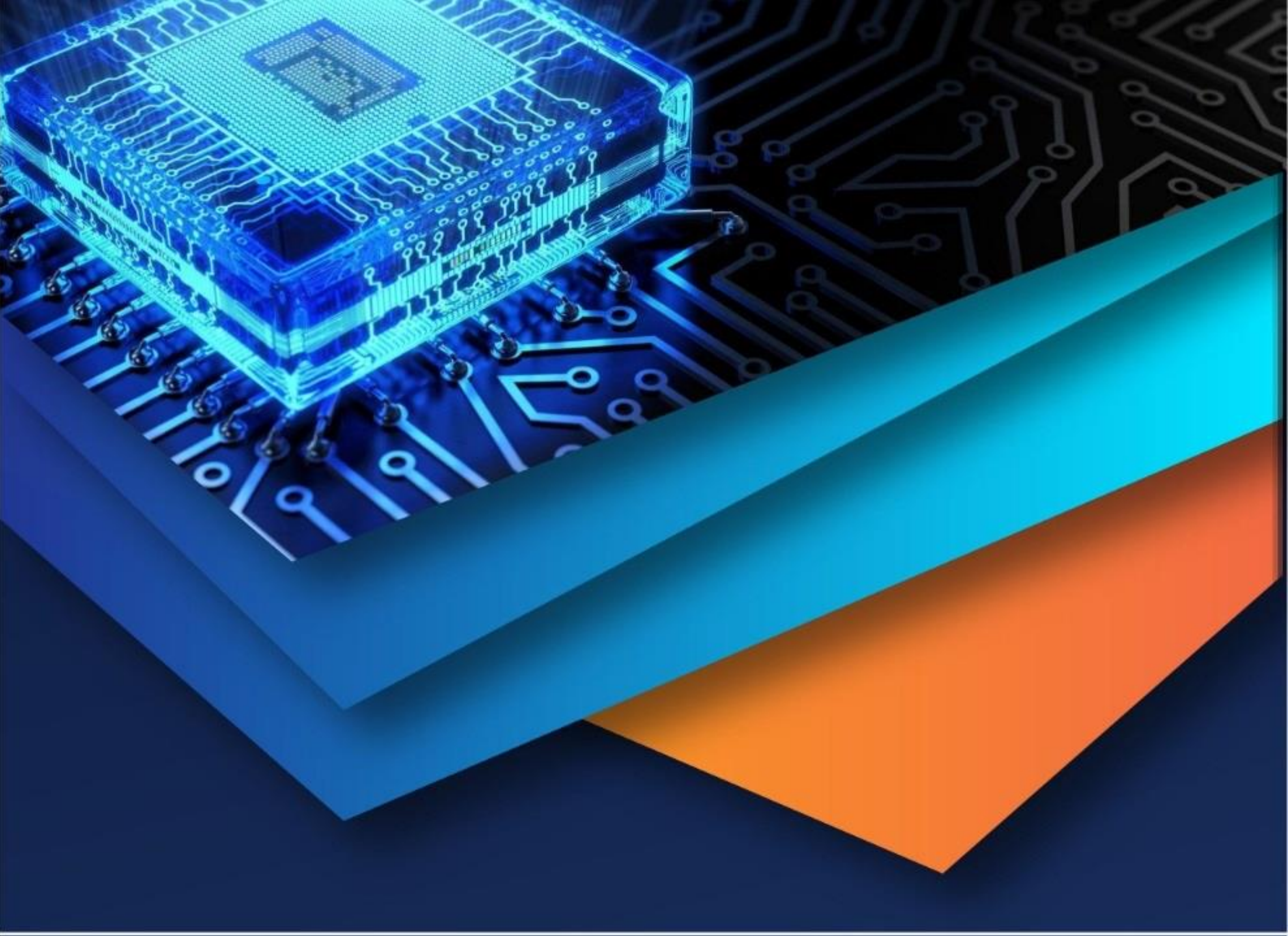

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