OPTIMIZED DESIGN & ANALYSIS OF STEEL PIPE RACKS FOR OIL & GAS INDUSTRIES AS PER INTERNATIONAL CODES & STANDARDS

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Abstract

Optimized Design of Steel Pipe rack supporting structures in an Oil & Gas Industry is complex as one of the most important parts of structural systems for safe and stable production processes have been studied in this paper. In this thesis we have tried to design the Steel Pipe rack 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.

Keywords: *Oil & Gas, Steel Pipe Rack, Transverse, Longitudinal Direction, Fireproofing, Staad Foundation, AISC Codes etc……*

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1. INTRODUCTION

Pipe networks are considered as main components of industrial complexes like refineries and petrochemicals that transfer fluid and gas and any damage in their structures may be dangerous.

Although the value of stability analysis has long been recognized, implementation in design has historically been difficult as calculations were performed primarily by hand. Various methods were created to simplify the analysis and allow the engineer to partially include the effects of stability via hand calculations. However, with the development of powerful analysis software, rigorous methods to account for stability effects were developed. While stability analysis calculations can still be done by hand, most engineers now have access to software that will complete a rigorous stability analysis. Stability analysis is a broad term that covers many aspects of the design process. According to the 2010 AISC Specification for Structural Steel Buildings (AISC 360-10) stability analysis shall consider the influence of second order effects (P-Δ and P-δ effects), flexural, shear and axial deformations, geometric imperfections, and member stiffness reduction due to residual stresses.

The main reason for life loss is collapse of structures It is said that natural calamities itself never kills people; it is badly constructed structure that kill. Hence it is important to analyze the structure properly for different natural calamities like earthquake, cyclones, floods and typhoons etc.

1.1 Wind Effect

ASCE 7-05 provides very little, if any guidance for application of wind load for pipe racks. The most appropriate application would be to assume the pipe rack is an open structure and design the structure assuming a design philosophy similar to that of a trussed tower. See Table 3-1 below for Cf, force coefficient. This method requires the engineer to calculate the ratio of solid area to gross area of one tower face for the segment under consideration. This may become very tedious for pipe rack structures because each face can have varying ratios of solids to gross areas.

Tower Cross Section	C_f
Square	$4.0\varepsilon^2-5.9\varepsilon+4.0$
Triangle	$3.4\varepsilon^2-4.7\varepsilon+3.4$

Force coefficient, Cf for open structures trussed towers (Adapted from ASCE 7-05)

The tributary area for structural steel members and other attachments should be based on the projected area of the object perpendicular to the direction of the wind. Because the structural members are typically spaced at greater distances than pipes, no shielding effects should be considered on structural members and the full wind pressures should be applied to each structural member.

The gust effect factor G, and the velocity pressure qz, should be determined based on ASCE 7-05 sections.

1.2 Earthquake Effect

Pipe racks are typically considered non-building structures, therefore seismic design should be carried out in accordance with ASCE 7-05, Chapter 15. A few slight variations from ASCE 7-05 are recommended. The operating earthquake load Eo is developed based on the operating dead load as part of the effective seismic weight. The empty earthquake load Ee is developed based on the empty dead load as part of the effective seismic weight. (Drake and Walter, 2010). The operating earthquake load and the empty earthquake load are discussed in more detail in the load combinations for pipe racks. Primary loads, Eo and Ee are developed and used in separate load combinations to envelope the seismic design of the pipe rack.

ASCE Guidelines for Seismic Evaluation and Design of Petrochemical Facilities (1997) also provides further guidance and information on seismic design of pipe racks. The ASCE guideline is however based on the 1994 Uniform Building Code (UBC) which has been superseded in most states by ASCE 7-05 or ASCE 7-10. Therefore the ASCE guideline should be considered as a reference document and not a design guideline.

2. LITERATURE REVIEW

Various literatures has presented in the form of technical papers till date. Some of those are discussed below:

- **David A. Nelson, Walla University, concluded that:**
  For the representative pipe rack 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 360-10.When the ratios $\Delta 2/\Delta 1$ and Pr/Py are below the list specified by AISC 360-10, all methods give comparable results. Several observations on each method can be made based on the analysis and results.

- **Preeti Rathore & Prof. D.H.Raval, (IJSRD, Vol.4 No.3, 2016),conclude that :**
  Base Shear in steel pipe rack is less than the combined pipe rack because of less seismic weight which gives better response during earthquake. As concrete gives better fire protection, so combined pipe rack will be more suitable than steel pipe rack.

- **Ali Reza Keyvani Boroujeni & Mehdi Hashemi, (Academic Journals, Vol.4 No.4, May-2013), concluded that:**
  This research paper concludes that, the petrochemical plants are contained in various pipes and industrial structures. Therefore, the applicable design methods are required. The scaling method has the advantage and is also applicable for structural design. Result of this evaluation show that scaling method satisfies the piping system performance for the supporting structures. Therefore, this method can be used for pipe rack and Pipe Bridge design. According to this result, the pipes which are being design should be controlled for differential displacement. So the scaling method is reliable for piping system design while the pipe is finally controlled.

- **Dr.D.P.Vakharia & Mohammad Farooq A, (IJRTE, Vol.1 No.6, 2009), :**
  Through this paper we tried to maximize the distance between supports keeping the values of stresses and deflection within safe limits. The aim is to reduce the number of supports to reduce the total cost of erection**.**

- **Richard Drake & Robert Walter (2014), conclude that:**
  Pipe Racks 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 pipe racks, 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.

3. DESCRIPTION OF STRUCTURE

A Piperack is carrying pipes supported at tier elevations TOS 107.000, 108.000, 110.000, 113.000 & 113.200.This pipe rack is modeled in STAAD PRO software and all reactions, forces and utility ratios are used for describing thesis thesis report.

Piperack PR-06A is 113.8m in lengthwise & Fire proofing is considered upto 9.0m for design as per Industries standards and AISC 2nd Edition.

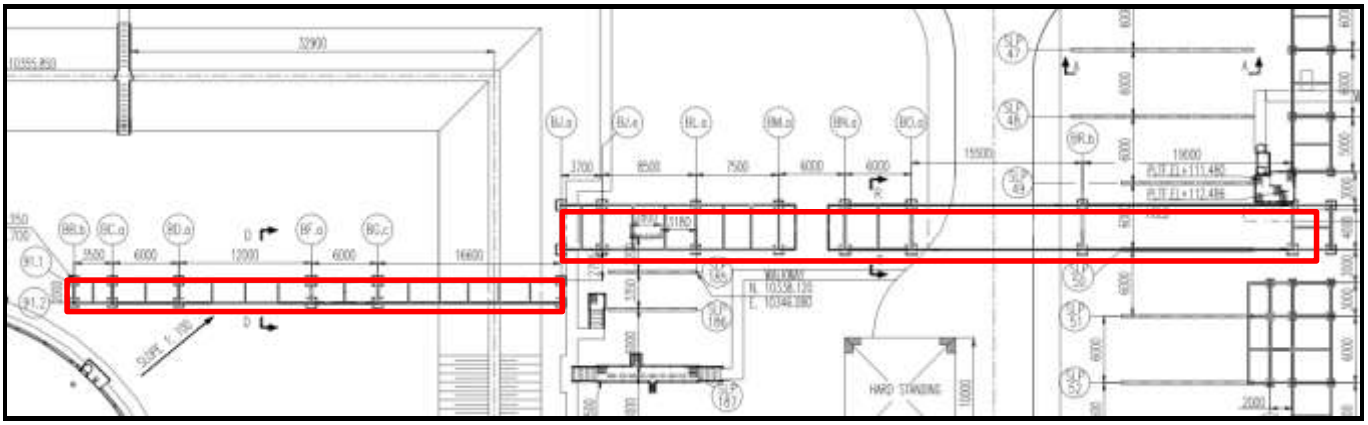


Fig.1 Keyplan PR-06 A

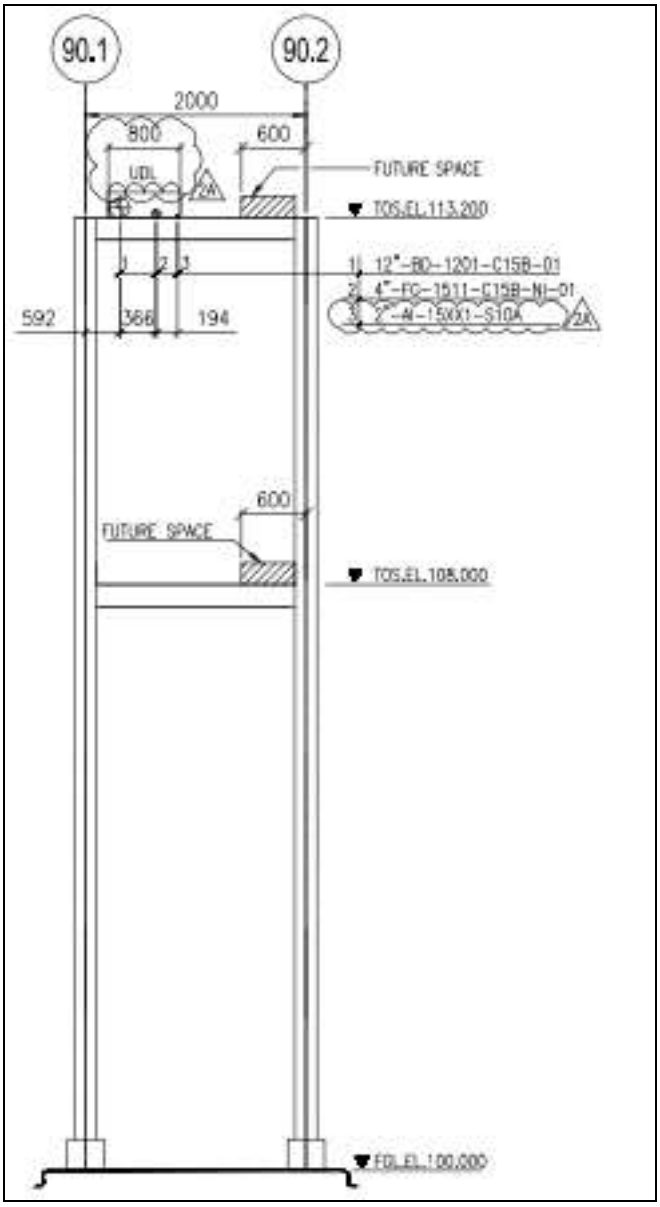


Fig.2 Section View Part-1

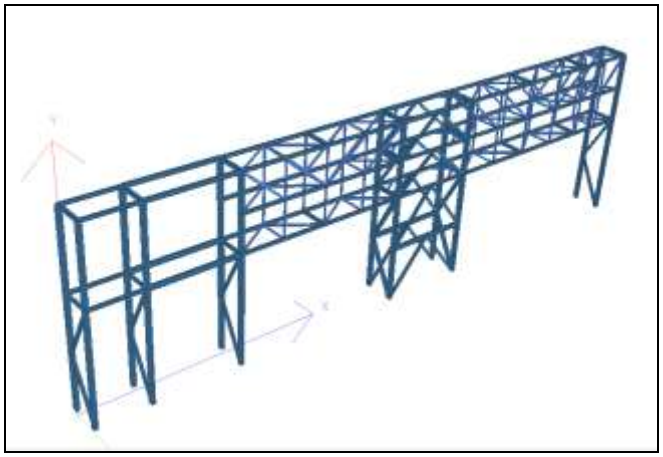


Fig.3 3-D VIEW

Piperack is designed as moment resisting frames in the transverse direction. The lateral forces in the transverse direction are transferred to base plate/ foundation by moment resisting frame. In the longitudinal direction, there is continuous level of beam struts on each side. Vertical bracing in the longitudinal direction is provided to carry the longitudinal forces, transmitted through the beam struts, to the base plate/ foundation level.

4. DESIGN LOAD CALCULATION

Basic loads are applied in Staad Model, as applicable, on the structure and its elements in form of 46 no.of Load Cases. Load Cases includes all the basic loads such as Dead loads, Live Loads, Wind, Seismic, Test loads, Operating loads, etc. Each load case is described in brief in this section. ASCE7-05 primary load cases are as follows

- 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
- Ext Wind in x Direction (WL +X & WL-X)
- Seismic X EQX

- Seismic X EQX
- Operating Blanket Load Vertical for checking
- minimum load Condition
- Operating Blanket Load frictional for checking
- minimum load Condition
- Operating Blanket Load Anchor for checking
- minimum load Condition

Basic wind speed, V = 45 m/s		Considered for Kuwait
Velocity pressure, qz = 0.613 x Kz x Kzt x Kd x V² x I = 0.61		Cl. 6.5.10 of ASCE7-05
Topographic factor, Kzt = 1		Cl. 6.5.7 of ASCE7-05
Wind directionality factor, Kd = 0.85		Table 6-4
Occupancy category = III		Table 1-1
Importance factor, I = 1.15		Table 6-1
Exposure C Cl.		6.5.6.3 of ASCE7-05
Velocity pressure exposure coefficient, Kz = 2.01*(Z/Zg) (2/α)		Table 6-3
Height of Structure	Z varies Zg = 274 m α = 9.5	Table 6-2 Table 6-2

Fig.4 Wind Load Data

Seismic X EQX :

Applicable Standard = UBC-97	(as per DBR Cl.7.1.6)
Seismic Zone = 1.0	(as per DBR Cl.7.1.6)
Zone Factor = 0.075	(as per Table 16-I of UBC)
Importance Factor, I = 1.50	(as per Table 16-K of UBC)
Response reduction factor, Rwx = 5.60	(as per Table 16-N of UBC)
Type of soil = Medium	

Fig.5 Seismic Load Data EQX

Seismic Z EQZ :

Applicable Standard = UBC-97	(as per DBR Cl.7.1.6)
Seismic Zone = 1.0	(as per DBR Cl.7.1.6)
Zone Factor = 0.075	(as per Table 16-I of UBC)
Importance Factor, I = 1.50	(as per Table 16-K of UBC)
Response reduction factor, Rwz = 4.20	(as per Table 16-N of UBC)
Type of soil = Medium	

Fig.6 Seismic Load Data EQZ

Various Primary load cases as mentioned above has been considered which are used worldwide in oil and gas industry to study the behavior of the structure and to get the proper Superstructure and Substructure sections.

Above Wind load and Seismic parameters has been applied in the present thesis and piping stress load from a standard organization in Kuwait has been used for loading the current geometry for lateral behavior of the structure.

5. DESIGN PARAMETERS

Design parameters has been applied in staad model under two different sections namely, Strength Design Check & Serviceability Check. Code LRFD has been used.

- **Strength Check**
  1) Tensile Strength 41368 kN/m2
  2) Yield Strength 275000 kN/m2
  3) Allowable L/R in compression 200
  4) LY, LZ,UNB & UNT to column and beams
  5) KZ 1.2 to columns
  6) Net Section Factor 0.9 to all beams
  7) Net Section Factor 0.6 to all bracings
  8) Utility Ratio 0.85 till 9.0m
  9) Utility Ratio 0.9 above 9.0m

- **Strength Check**
  1) Deflection DJ1 & DJ2 to all beams
  2) DFF 300 to all beams
  3) Utility Ratio 0.85 till 9.0m
  4) Utility Ratio 0.9 above 9.0m

6. STAAD RESULTS

Different Results obtained from the Staad model has been represented here in the form of images:

6.1 Sway Check

Model	Node No.	Load Case	Max Deflection (mm)	Frame Height (upper Tier) (mm)	Allowable Deflection H/200 (mm)
PR-06A	256	511	35.00	13.2	66

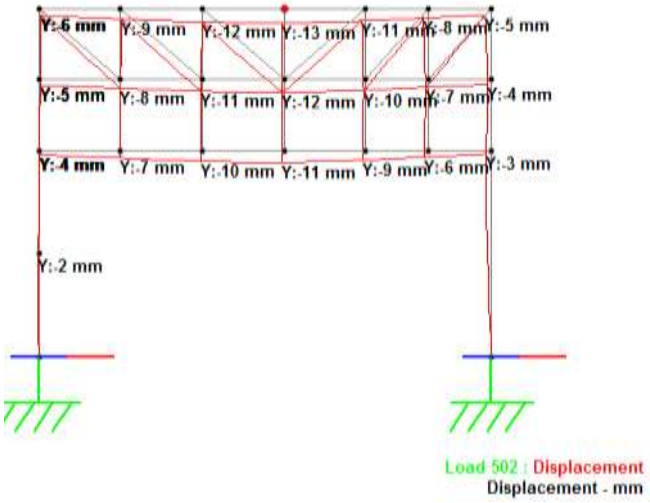
PR-06-1_10-05-16-A - Node Displacements: G1: _FRAME_DEFL(2M)

All / Summary

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm
Max X	216	502 1DL+1EO+1TF+1TV(-VE)+1TA	13	-5	4
Min X	256	504 1DL+1EO-1TF+1TV(-VE)-1TA	-11	-5	-8
Max Y	250	503 1DL+1EO-1TF+1TV(+VE)-1TA	-1	5	-13
Min Y	250	502 1DL+1EO+1TF+1TV(-VE)+1TA	2	-6	13
Max Z	256	511 1DL+1EO+1LL+1TF+1TA+1WL +Z	1	-1	35
Min Z	256	520 1DL+1EO+1LL-1TF-1TA+1WL -Z	-4	0	-35
Max rX	187	511 1DL+1EO+1LL+1TF+1TA+1WL +Z	3	-1	8
Min rX	187	520 1DL+1EO+1LL-1TF-1TA+1WL -Z	-3	0	-8
Max rY	228	520 1DL+1EO+1LL-1TF-1TA+1WL -Z	-2	-2	-34
Min rY	228	511 1DL+1EO+1LL+1TF+1TA+1WL +Z	3	1	34
Max rZ	234	1515 1DL+1BLNV+1LL+1BLNF+1BLNA+1(WL+X-Z)+WI	2	-1	-14
Min rZ	187	1501 1DL+1BLNV+1BLNF+1TV(+VE)+1BLNA	9	2	1
Max Rs	256	511 1DL+1EO+1LL+1TF+1TA+1WL +Z	1	-1	35

6.1 Storey Drift Check

Tier Level	Height (m)	Displacement (mm)	Allowable displacement H/150 (mm)
108.00	7.6	8.0	50.67
113.20	5.2	27.0	34.67



6.3 Vertical Deflection Check for Bridge

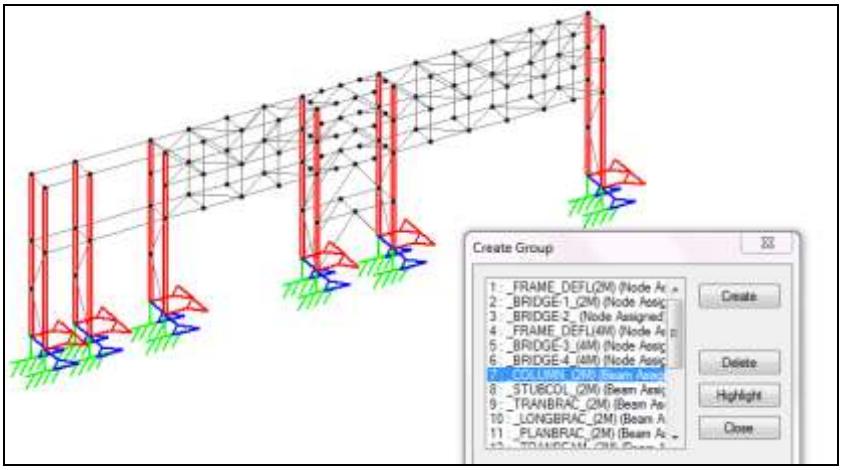
SL. NO.	Grid Mark	Node No.	L/C	Vert.Deflection (mm)	Span of Bridge (m)	Allowable Deflection L/300 (mm)	Remarks
1	BD.a - BF.a	222	504	9.00	12	40.0	O.K
2	BG.c - BJ.a	253	502	13.00	16.6	55.3	O.K

6.4 Utility Ratio Check

6.4.1 Columns

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
1498	UC254X254X89	UC254X254X89	0.265	0.900	0.294	LRFD-H1-1B-	611
1500	UC254X254X89	UC254X254X89	0.273	0.900	0.303	LRFD-H1-1B-	620
1194	UC254X254X89	UC254X254X89	0.294	0.850	0.346	LRFD-H1-1B-	611
1390	UC254X254X89	UC254X254X89	0.294	0.850	0.346	LRFD-H1-1B-	620
1096	UC254X254X89	UC254X254X89	0.300	0.850	0.352	LRFD-H1-1A	620
3057	UC254X254X89	UC254X254X89	0.301	0.850	0.354	LRFD-H1-1B-	1620
1935	UC254X254X89	UC254X254X89	0.313	0.900	0.347	LRFD-H1-1B-	611
1145	UC254X254X89	UC254X254X89	0.316	0.850	0.372	LRFD-H1-1A	1611
1148	UC254X254X89	UC254X254X89	0.333	0.850	0.392	LRFD-H1-1B-	620
1196	UC254X254X89	UC254X254X89	0.339	0.850	0.399	LRFD-H1-1B-	620
1934	UC254X254X89	UC254X254X89	0.348	0.900	0.386	LRFD-H1-1B-	620
1146	UC254X254X89	UC254X254X89	0.349	0.850	0.411	LRFD-H1-1B-	611
1394	UC254X254X89	UC254X254X89	0.384	0.850	0.451	LRFD-H1-1B-	620
3064	UC254X254X89	UC254X254X89	0.405	0.850	0.476	LRFD-H1-1B-	620
1392	UC254X254X89	UC254X254X89	0.451	0.850	0.531	LRFD-H1-1A	611
1121	UC254X254X89	UC254X254X89	0.466	0.850	0.548	LRFD-H1-1A	1611
1170	UC254X254X89	UC254X254X89	0.487	0.850	0.573	LRFD-H1-1B-	611
1172	UC254X254X89	UC254X254X89	0.493	0.850	0.580	LRFD-H1-1B-	620
1120	UC254X254X89	UC254X254X89	0.495	0.850	0.582	LRFD-H1-1A	1620
1169	UC254X254X89	UC254X254X89	0.533	0.850	0.627	LRFD-H1-1A	611
1144	UC254X254X89	UC254X254X89	0.541	0.850	0.637	LRFD-H1-1A	620
1168	UC254X254X89	UC254X254X89	0.617	0.850	0.726	LRFD-H1-1A	636
1193	UC254X254X89	UC254X254X89	0.629	0.850	0.740	LRFD-H1-1A	611
1192	UC254X254X89	UC254X254X89	0.630	0.850	0.742	LRFD-H1-1A	620
1396	UC254X254X89	UC254X254X89	0.645	0.850	0.759	LRFD-H1-1A	611

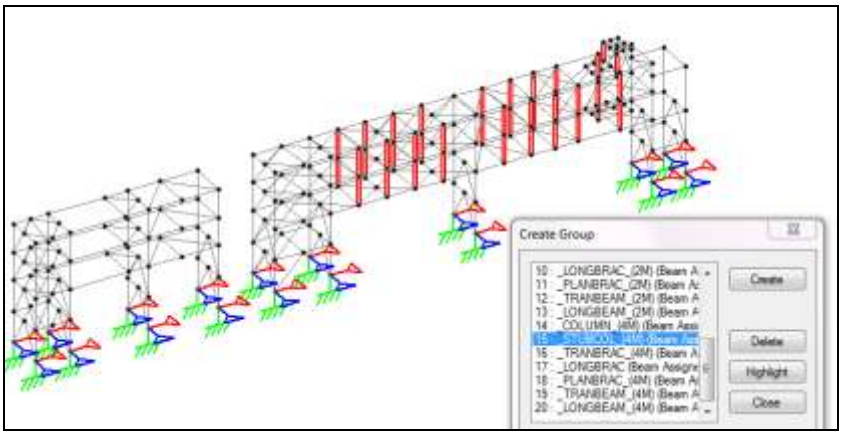


6.4.2 Stub Columns

PR-06-1_10-05-16-A - Design Results:- G18: _STUBCOL_(4M)

All / Failed Members

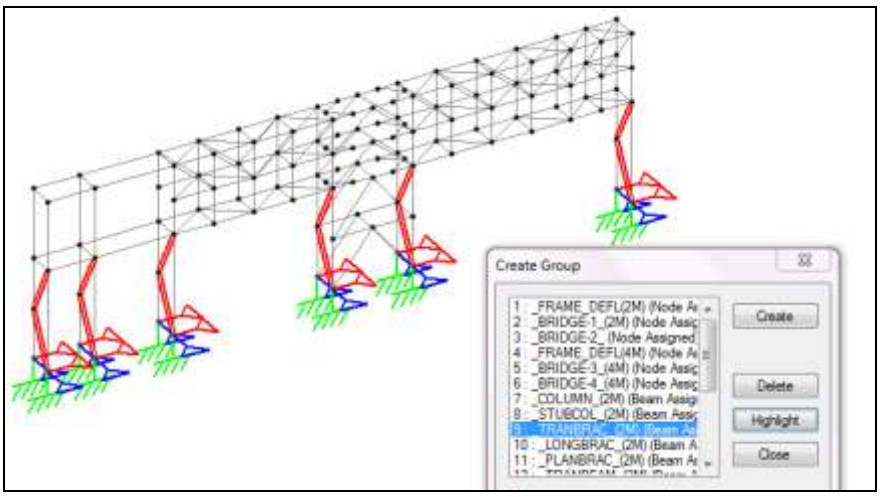
Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/(
3114	UB203X133X25 T	UB203X133X25 T	0.173	0.900	0.193	LRFD-H1-1B-	623
3104	UB203X133X25 T	UB203X133X25 T	0.181	0.900	0.201	LRFD-H1-1B-	613
3105	UB203X133X25 T	UB203X133X25 T	0.203	0.850	0.239	LRFD-H1-1B-	613
3115	UB203X133X25 T	UB203X133X25 T	0.204	0.850	0.240	LRFD-H1-1B-	613
3107	UB203X133X25 T	UB203X133X25 T	0.212	0.850	0.249	LRFD-H1-1B-	624
3193	UC152X152X23	UC152X152X23	0.277	0.850	0.326	LRFD-H1-1A	604
3102	UC152X152X23	UC152X152X23	0.279	0.900	0.310	LRFD-H1-1A	624
2199	UC152X152X23	UC152X152X23	0.323	0.900	0.359	LRFD-H1-1A	611
3116	UC152X152X23	UC152X152X23	0.328	0.900	0.364	LRFD-H1-1A	622
3112	UB203X133X25 T	UB203X133X25 T	0.330	0.900	0.367	LRFD-H1-1A	1613
3186	UC152X152X23	UC152X152X23	0.362	0.900	0.402	LRFD-H1-1A	603
3106	UB203X133X25 T	UB203X133X25 T	0.378	0.900	0.420	LRFD-H1-1A	1613
3113	UB203X133X25 T	UB203X133X25 T	0.387	0.850	0.455	LRFD-H1-1A	624
3108	UC152X152X23	UC152X152X23	0.425	0.900	0.472	LRFD-H1-1A	601
2194	UC152X152X23	UC152X152X23	0.467	0.850	0.550	LRFD-H1-1B-	601
3110	UC152X152X23	UC152X152X23	0.509	0.900	0.566	LRFD-H1-1A	601
2200	UC152X152X23	UC152X152X23	0.518	0.900	0.575	LRFD-H1-1A	618
3184	UC152X152X23	UC152X152X23	0.530	0.900	0.589	LRFD-H1-1A	601
3180	UC152X152X23	UC152X152X23	0.567	0.900	0.630	LRFD-H1-1A	603
2853	UC152X152X23	UC152X152X23	0.589	0.900	0.654	LRFD-H1-1A	618
2978	UC203X203X46	UC203X203X46	0.627	0.850	0.738	LRFD-H1-1B-	616
2970	UC152X152X37	UC152X152X37	0.652	0.900	0.725	LRFD-H1-1A	621
2971	UC152X152X37	UC152X152X37	0.704	0.900	0.783	LRFD-H1-1A	615
2976	UC152X152X37	UC152X152X37	0.712	0.900	0.791	LRFD-H1-1A	615
3182	UC152X152X23	UC152X152X23	0.735	0.900	0.816	LRFD-H1-1A	601



6.4.3 Transverse Bracing

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
3052	UC152X152X23	UC152X152X23	0.328	0.850	0.386	LRFD-H1-1A	1620
3061	UC203X203X46	UC203X203X46	0.390	0.850	0.459	LRFD-H1-1A	611
3056	UC152X152X23	UC152X152X23	0.391	0.850	0.460	LRFD-H1-1A	611
3060	UC203X203X46	UC203X203X46	0.399	0.850	0.469	LRFD-H1-1A	620
3055	UC152X152X23	UC152X152X23	0.423	0.850	0.497	LRFD-H1-1A	1620
3063	UC203X203X46	UC203X203X46	0.547	0.850	0.644	LRFD-H1-1A	611
3062	UC203X203X46	UC203X203X46	0.568	0.850	0.668	LRFD-H1-1A	620
3066	UC152X152X30	UC152X152X30	0.630	0.850	0.741	LRFD-H1-1A	611
3059	UC152X152X23	UC152X152X23	0.663	0.850	0.780	LRFD-H1-1A	1611
3065	UC152X152X30	UC152X152X30	0.739	0.850	0.870	LRFD-H1-1A	620
3058	UC152X152X23	UC152X152X23	0.760	0.850	0.894	LRFD-H1-1A	1620

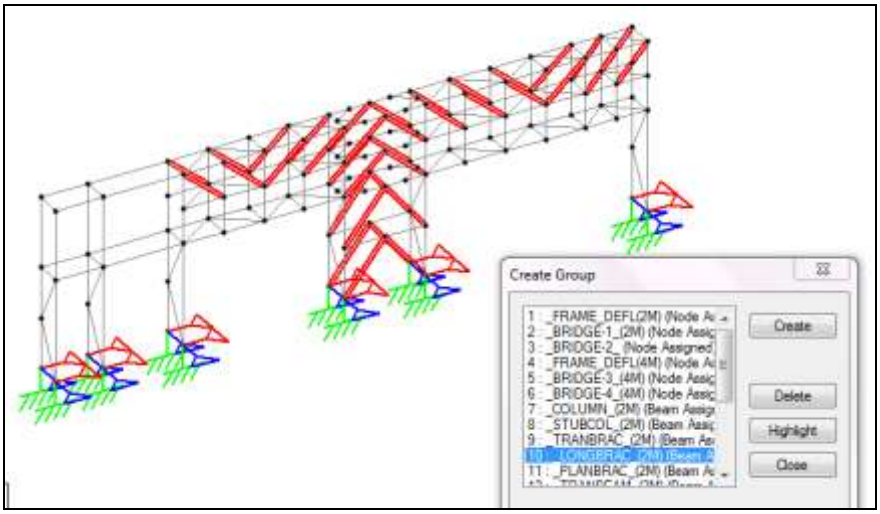


6.4.4 Longitudinal Bracing

PR-06-1_10-05-16-A - Design Results:- G10: _LONGBRAC_(2M)

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L
2086	UB254X146X31 T	UB254X146X31 T	0.276	0.900	0.307	LRFD-H1-1B-	1619
1613	UC152X152X23	UC152X152X23	0.280	0.850	0.329	LRFD-H1-1A	613
1612	UC152X152X23	UC152X152X23	0.288	0.850	0.338	LRFD-H1-1A	622
2089	UB305X165X40 T	UB305X165X40 T	0.340	0.900	0.378	LRFD-H1-1A	1613
2095	UB305X165X40 T	UB305X165X40 T	0.341	0.900	0.378	LRFD-H1-1A	1637
2624	UB254X146X31 T	UB254X146X31 T	0.362	0.900	0.403	LRFD-H1-1A	1637
2623	UB254X146X31 T	UB254X146X31 T	0.383	0.900	0.425	LRFD-H1-1A	1613
2519	UB254X146X31 T	UB254X146X31 T	0.393	0.900	0.437	LRFD-H1-1A	624
2520	UB254X146X31 T	UB254X146X31 T	0.393	0.900	0.437	LRFD-H1-1A	1624
2998	UB254X146X31 T	UB254X146X31 T	0.393	0.900	0.436	LRFD-H1-1A	615
2999	UB254X146X31 T	UB254X146X31 T	0.410	0.900	0.455	LRFD-H1-1A	1615
2090	UB305X165X40 T	UB305X165X40 T	0.457	0.900	0.508	LRFD-H1-1A	632
2084	UB305X165X40 T	UB305X165X40 T	0.461	0.900	0.512	LRFD-H1-1A	1624
2622	UB254X146X31 T	UB254X146X31 T	0.481	0.900	0.535	LRFD-H1-1A	632
2526	UB254X146X31 T	UB254X146X31 T	0.483	0.900	0.537	LRFD-H1-1A	1615
2525	UB254X146X31 T	UB254X146X31 T	0.494	0.900	0.549	LRFD-H1-1A	615
2620	UB254X146X31 T	UB254X146X31 T	0.517	0.900	0.574	LRFD-H1-1A	1624
1472	UC152X152X30	UC152X152X30	0.624	0.850	0.735	LRFD-H1-1A	618
1473	UC152X152X30	UC152X152X30	0.629	0.850	0.740	LRFD-H1-1A	609
1478	UC152X152X30	UC152X152X30	0.646	0.850	0.760	LRFD-H1-1A	618
1479	UC152X152X30	UC152X152X30	0.648	0.850	0.762	LRFD-H1-1A	609
1474	UC152X152X30	UC152X152X30	0.677	0.850	0.797	LRFD-H1-1A	609
1475	UC152X152X30	UC152X152X30	0.680	0.850	0.800	LRFD-H1-1A	618
1476	UC152X152X30	UC152X152X30	0.693	0.850	0.815	LRFD-H1-1A	618
1477	UC152X152X30	UC152X152X30	0.694	0.850	0.816	LRFD-H1-1A	609

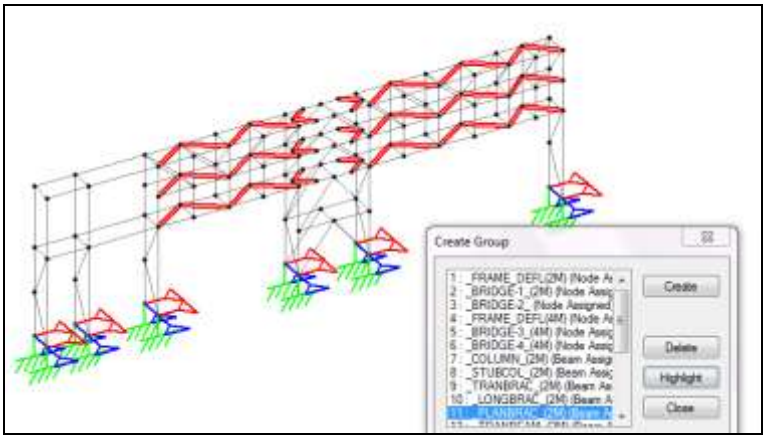


6.4.5 Plan Bracing

PR-06-1_10-05-16-A - Design Results:- G11: _PLANBRAC_(2M)

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L
2321	UB203X133X25 Te	UB203X133X25 Te	0.209	0.900	0.232	LRFD-H1-1B-	1624
2701	UB203X133X25 Te	UB203X133X25 Te	0.217	0.900	0.241	LRFD-H1-1B-	1613
3046	UB203X133X25 Te	UB203X133X25 Te	0.227	0.900	0.252	LRFD-H1-1B-	1629
2327	UB203X133X25 Te	UB203X133X25 Te	0.239	0.900	0.266	LRFD-H1-1B-	631
2320	UB203X133X25 Te	UB203X133X25 Te	0.240	0.900	0.266	LRFD-H1-1B-	1613
3048	UB203X133X25 Te	UB203X133X25 Te	0.245	0.900	0.273	LRFD-H1-1B-	1628
2326	UB203X133X25 Te	UB203X133X25 Te	0.266	0.900	0.296	LRFD-H1-1B-	1637
2700	UB203X133X25 Te	UB203X133X25 Te	0.274	0.900	0.305	LRFD-H1-1A	680
2329	UB203X133X25 Te	UB203X133X25 Te	0.325	0.900	0.361	LRFD-H1-1A	1611
2318	UB254X146X31 Te	UB254X146X31 Te	0.350	0.850	0.411	LRFD-H1-1B-	622
2322	UB203X133X25 Te	UB203X133X25 Te	0.359	0.900	0.399	LRFD-H1-1A	1628
2319	UB254X146X31 Te	UB254X146X31 Te	0.362	0.850	0.426	LRFD-H1-1B-	616
2311	UB254X146X31 Te	UB254X146X31 Te	0.445	0.850	0.523	LRFD-H1-1B-	1623
2316	UB254X146X31 Te	UB254X146X31 Te	0.445	0.850	0.523	LRFD-H1-1B-	1637
2312	UB254X146X31 Te	UB254X146X31 Te	0.450	0.850	0.530	LRFD-H1-1B-	622
3049	UB203X133X25 Te	UB203X133X25 Te	0.450	0.900	0.500	LRFD-H1-1A	635
2317	UB254X146X31 Te	UB254X146X31 Te	0.453	0.850	0.533	LRFD-H1-1B-	632
2315	UB254X146X31 Te	UB254X146X31 Te	0.465	0.850	0.547	LRFD-H1-1B-	631
2310	UB254X146X31 Te	UB254X146X31 Te	0.466	0.850	0.548	LRFD-H1-1B-	1613
2323	UB203X133X25 Te	UB203X133X25 Te	0.469	0.900	0.521	LRFD-H1-1A	635
2313	UB254X146X31 Te	UB254X146X31 Te	0.472	0.850	0.556	LRFD-H1-1B-	616
2314	UB254X146X31 Te	UB254X146X31 Te	0.489	0.850	0.576	LRFD-H1-1B-	1635
2699	UB203X133X25 Te	UB203X133X25 Te	0.494	0.900	0.549	LRFD-H1-1A	1611
2325	UB203X133X25 Te	UB203X133X25 Te	0.540	0.900	0.600	LRFD-H1-1A	628
2324	UB203X133X25 Te	UB203X133X25 Te	0.642	0.900	0.713	LRFD-H1-1A	1635

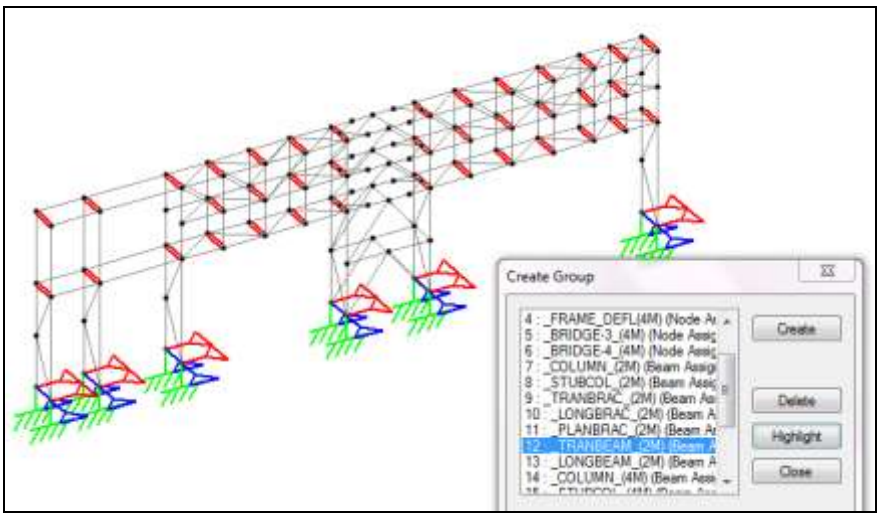


6.4.6 Transverse Beam

PR-06-1_10-05-16-A - Design Results:- G12: _TRANBEAM_(2M)

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C
1150	UB254X146X37	UB254X146X37	0.188	0.850	0.221	LRFD-H1-1B-	1611
2960	UB254X146X37	UB254X146X37	0.191	0.850	0.225	LRFD-H1-1B-	1611
1174	UC254X254X73	UC254X254X73	0.223	0.850	0.262	LRFD-H1-1B-	1603
1080	UB254X146X37	UB254X146X37	0.235	0.900	0.261	LRFD-H1-1B-	620
1350	UB203X133X25	UB203X133X25	0.262	0.900	0.291	LRFD-H1-1B-	601
2096	UB203X133X25	UB203X133X25	0.262	0.900	0.291	LRFD-H1-1B-	603
2102	UB203X133X25	UB203X133X25	0.262	0.900	0.291	LRFD-H1-1B-	603
1356	UB203X133X25	UB203X133X25	0.269	0.850	0.316	LRFD-H1-1B-	602
2099	UB203X133X25	UB203X133X25	0.269	0.850	0.316	LRFD-H1-1B-	602
2103	UB203X133X25	UB203X133X25	0.269	0.850	0.316	LRFD-H1-1B-	602
1078	UB203X133X25	UB203X133X25	0.273	0.850	0.321	LRFD-H1-1B-	603
1102	UB203X133X25	UB203X133X25	0.273	0.850	0.321	LRFD-H1-1B-	603
1126	UB203X133X25	UB203X133X25	0.275	0.850	0.323	LRFD-H1-1B-	1603
1198	UB203X133X25	UB203X133X25	0.283	0.850	0.333	LRFD-H1-1B-	613
1371	UC254X254X73	UC254X254X73	0.286	0.900	0.317	LRFD-H1-1B-	611
1176	UC254X254X73	UC254X254X73	0.300	0.900	0.333	LRFD-H1-1B-	611
1104	UB254X146X37	UB254X146X37	0.305	0.900	0.339	LRFD-H1-1B-	620
1369	UB254X146X37	UB254X146X37	0.340	0.900	0.378	LRFD-H1-1B-	611
2939	UB457X191X67	UB457X191X67	0.352	0.900	0.392	LRFD-H1-1B-	620
3037	UB457X191X67	UB457X191X67	0.354	0.900	0.393	LRFD-H1-1B-	611
1152	UB254X146X37	UB254X146X37	0.357	0.900	0.397	LRFD-H1-1B-	620
1933	UB457X191X67	UB457X191X67	0.507	0.900	0.564	LRFD-H1-1B-	620
3036	UB457X191X67	UB457X191X67	0.507	0.900	0.563	LRFD-H1-1B-	611
1128	UB254X146X37	UB254X146X37	0.553	0.900	0.614	LRFD-H1-1B-	620
1200	UB254X146X37	UB254X146X37	0.769	0.900	0.854	LRFD-H1-1B-	620

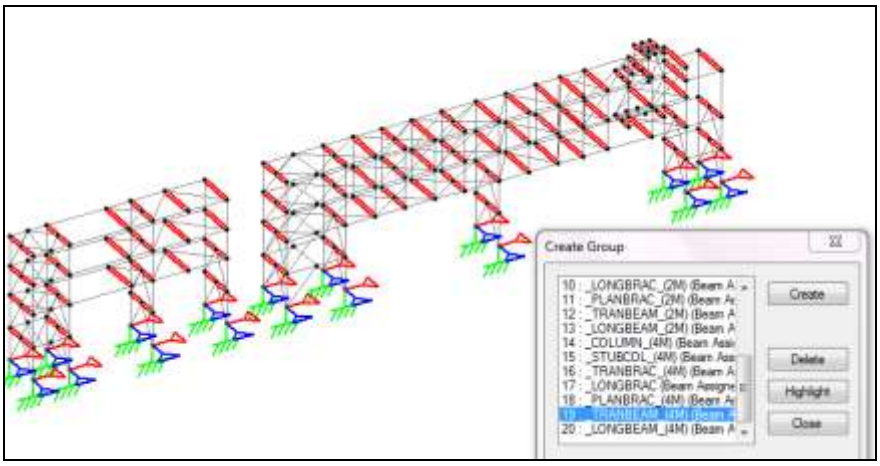


6.4.7 Longitudinal Beam

PR-06-1_10-05-16-A - Design Results:- G22: _TRANBEAM_(4M)

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/
1739	UB305X165X40	UB305X165X40	0.633	0.850	0.745	LRFD-H1-1A	613
2983	UB203X133X25	UB203X133X25	0.641	0.850	0.754	LRFD-H1-1B-	610
3014	UB203X133X25	UB203X133X25	0.644	0.850	0.757	LRFD-H1-1B-	610
3160	UB254X146X37	UB254X146X37	0.654	0.900	0.727	LRFD-H1-1B-	604
3158	UB254X146X37	UB254X146X37	0.657	0.900	0.730	LRFD-H1-1B-	601
3220	UB254X146X37	UB254X146X37	0.658	0.900	0.731	LRFD-H1-1B-	601
1734	UC305X305X118	UC305X305X118	0.662	0.900	0.735	LRFD-H1-1B-	620
1744	UB305X165X40	UB305X165X40	0.681	0.850	0.801	LRFD-H1-1A	622
1721	UC254X254X73	UC254X254X73	0.684	0.850	0.804	LRFD-H1-1B-	602
2610	UC203X203X46	UC203X203X46	0.706	0.900	0.785	LRFD-H1-1B-	1620
1740	UC203X203X71	UC203X203X71	0.708	0.900	0.787	LRFD-H1-1B-	620
1685	UC254X254X73	UC254X254X73	0.710	0.850	0.835	LRFD-H1-1B-	602
1644	UB305X165X40	UB305X165X40	0.716	0.900	0.796	LRFD-H1-1B-	620
2162	UC203X203X71	UC203X203X71	0.717	0.850	0.844	LRFD-H1-1B-	602
2647	UB305X165X40	UB305X165X40	0.720	0.900	0.800	LRFD-H1-1B-	611
2906	UB305X165X40	UB305X165X40	0.724	0.900	0.805	LRFD-H1-1B-	611
2214	UC254X254X89	UC254X254X89	0.729	0.850	0.858	LRFD-H1-1B-	602
3221	UC203X203X60	UC203X203X60	0.740	0.900	0.822	LRFD-H1-1B-	611
1668	UB305X165X40	UB305X165X40	0.744	0.900	0.827	LRFD-H1-1B-	620
1667	UB305X165X40	UB305X165X40	0.751	0.850	0.884	LRFD-H1-1B-	603
1680	UC203X203X60	UC203X203X60	0.751	0.900	0.834	LRFD-H1-1B-	1620
1698	UC203X203X46	UC203X203X46	0.760	0.900	0.845	LRFD-H1-1B-	620
2207	UC203X203X46	UC203X203X46	0.773	0.850	0.909	LRFD-H1-1B-	602
1686	UB254X146X37	UB254X146X37	0.776	0.900	0.862	LRFD-H1-1B-	620
1752	UC254X254X89	UC254X254X89	0.825	0.900	0.917	LRFD-H1-1B-	620



6.4.8 Check for longitudinal tie beam

As per Industries longitudinal tie beams are to be checked for additional axial load of 15% of adjacent column load.

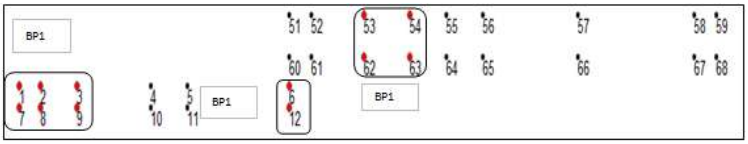
Tie Properties	Actual utility ratio	Column axial load (kN)	15 % of Column axial load (kN)	Axial capacity of tie (kN)	Combined utility ratio
At TOS. EL. 108.000					
UB305X165X40	0.482	362.9	54.435	320.08	0.65
At TOS. EL. 113.200					
UB254X136X37	0.598	135.92	20.388	239.22	0.68

6.4.9 Support Reaction Summary

6.4.9.1 Base Plate – 1

All / Summary / Envelope

	Node	L/C	Horizontal Fx kN	Vertical Fy kN	Horizontal Fz kN
Max Fx	63	618 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -X	**4.004**	55.263	41.083
Min Fx	63	609 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6WL +X	**-4.029**	419.293	-51.357
Max Fy	53	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	0.212	**905.640**	114.246
Min Fy	12	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	0.272	**-425.102**	115.721
Max Fz	12	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	0.272	-425.102	**115.721**
Min Fz	12	611 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6WL +Z	0.073	744.871	**-116.300**
Max Mx	1	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	0.495	78.710	1.094
Min Mx	1	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	0.495	78.710	1.094
Max My	63	615 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6(WL+X-Z)+WI	-3.137	238.407	-10.320
Min My	63	624 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6(WL-X+Z)+WI	3.113	236.150	0.046
Max Mz	1	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	0.495	78.710	1.094
Min Mz	1	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	0.495	78.710	1.094



Size of Base Plate : 625 X 500 x 30 mm

Size of Stiffner Plate : 245 X 12 mm

Anchor Bolts : 4 - M30

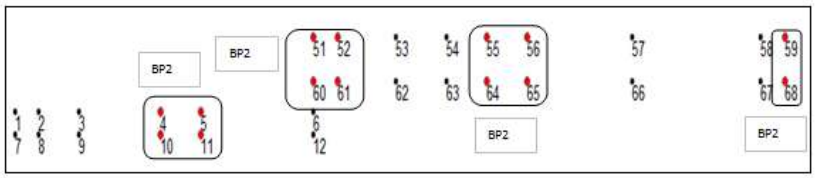
Fillet weld thick between stiffner plate and base plate : 8 mm

Fillet weld thick between Steel column and base plate : 8 mm

6.4.9.2 Base Plate – 2

All / Summary / Envelope

	Node	L/C	Horizontal Fx kN	Vertical Fy kN	Horizontal Fz kN
Max Fx	55	618 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -X	**328.225**	1179.224	18.787
Min Fx	56	609 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6WL +X	**-321.537**	1251.466	-27.404
Max Fy	65	613 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6(WL+X+Z)+WI	-263.798	**1546.067**	-103.151
Min Fy	11	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	39.220	**-968.359**	222.178
Max Fz	11	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	39.220	-968.359	**222.178**
Min Fz	11	611 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6WL +Z	-50.692	1486.721	**-225.312**
Max Mx	4	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-60.505	-89.755	1.399
Min Mx	4	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-60.505	-89.755	1.399
Max My	11	1627 1.2DL+1.2BLNV+1.2BLNA+1.6WL +Z	-22.033	1347.341	-214.639
Min My	11	636 1.2DL+1.2EO-1.2TA+1.6WL -Z	10.539	-827.570	211.604
Max Mz	4	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-60.505	-89.755	1.399
Min Mz	4	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-60.505	-89.755	1.399

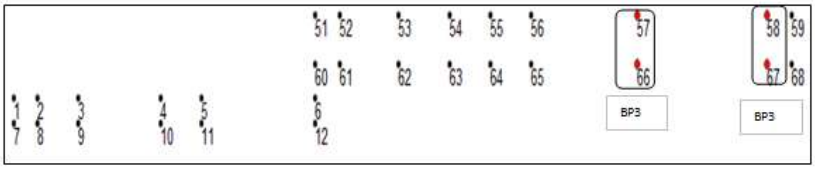


Size of Base Plate	:	650 X 650 x 45 mm
Size of Stiffner Plate	:	320 X 12 mm
Anchor Bolts	:	4 - M42
Fillet weld thick between stiffner plate and base plate	:	8 mm
Fillet weld thick between Steel column and base plate	:	8 mm

6.4.9.3 Base Plate – 3

All / Summary / Envelope

	Node	L/C	Horizontal Fx kN	Vertical Fy kN	Horizontal Fz kN
Max Fx	58	618 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -X	**9.093**	913.273	44.152
Min Fx	58	609 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6WL +X	**-7.583**	462.411	-43.410
Max Fy	57	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	0.417	**2190.527**	319.934
Min Fy	66	680 0.9DL+0.9EE+1.6WL -Z	-0.507	**-689.439**	203.594
Max Fz	57	620 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -Z	0.417	2190.527	**319.934**
Min Fz	66	611 1.2DL+1.2EO+1LL+1.2TF+1.2TA+1.6WL +Z	-0.007	1908.064	**-305.859**
Max Mx	57	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-4.420	625.599	-95.346
Min Mx	57	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-4.420	625.599	-95.346
Max My	58	677 0.9DL+0.9EE+1.6WL +X	-6.108	251.979	-0.990
Min My	58	618 1.2DL+1.2EO+1LL-1.2TF-1.2TA+1.6WL -X	9.093	913.273	44.152
Max Mz	57	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-4.420	625.599	-95.346
Min Mz	57	601 1.4DL+1.4EO+1.4TF+1.4TV(+VE)+1.4TA	-4.420	625.599	-95.346



Size of Base Plate	:	650 X 500 x 40 mm
Size of Stiffner Plate	:	244 X 12 mm
Anchor Bolts	:	4 - M36
Fillet weld thick between stiffner plate and base plate	:	10 mm
Fillet weld thick between Steel column and base plate	:	8 mm

7. FOUNDATION DESIGN

7.1 Input Parameters

Data Input Pane

Concrete and Reinforcement

Unit weight of concrete	25	kN/m3
Minimum bar spacing	50	mm
Maximum bar spacing	450	mm
Strength of concrete	24	N/mm2
Yield strength of steel	415	N/mm2
Minimum Footing bar size	16	
Maximum Footing bar size	20	
Top Min Footing Bar size	16	
Top Max Footing Bar size	20	
Minimum Pedestal Bar Size	12	
Maximum Pedestal Bar Size	20	
Set as Default	No	

For Combined foundation Super structure's support reactions and locations are directly imported to STAAD foundation and analyzed & designed in STAAD Foundation Software & for Mat foundation MAT3D software has been used.

Data Input Pane

Cover and Soil

Pedestal Clear Cover	75	mm
Footing Clear Cover	75	mm
Unit weight of Soil	20	kN/m3
Soil bearing capacity	285	kN/m2
Footing Embedment Depth	1.75	m
Type of Depth	Fixed Bottom	
Surcharge for loading	0	kN/m2
Depth of Water Table	10	m
Min % of Contact Area	90	
Set as Default	No	

Fig.7 Staad Foundation Input

7.2 Summary of Results from STAAD Foundation

Sr No.	Foundation Marked	Foundation Size (m)			Rebar	
		L	B	T	Top	Bottom
1	CF1	4.0	2.4	0.5	T16@200	T16@200
2	CF2	4.2	3.6	0.5	T16@200	T16@200
3	CF3	6.0	4.0	0.75	T16@125	T16@125
4	CF4	4.4	4.0	0.5	T16@150	T16@150
5	CF5	6.2	2.8	0.5	T16@200	T16@200
6	CF6	8.0	4.2	0.5	T16@125	T16@125
9	MF1	8.2	6.5	0.6	T16@175	T20@175
8	MF2	9.8	7.9	0.8	T16@175	T20@175
10	MF3	7.0	6.9	0.5	T16@175	T16@175

Summary of Foundation Design Results

7.3 Pedestals FOR PR-06A

Pedestal Marked	Pedestal Size (mm)		Vertical Rebar	Stirrups
	Length	Width		
P1	900	900	20-T20	T10@200
P2	1000	1000	20-T20	T10@200
P3	1000	1000	20-T20	T10@200

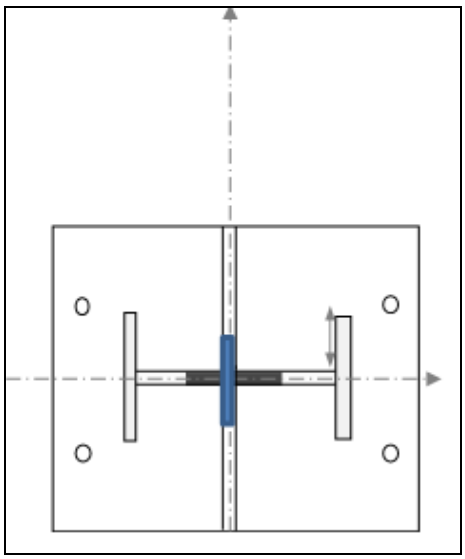
Fig.7 Staad Foundation Input

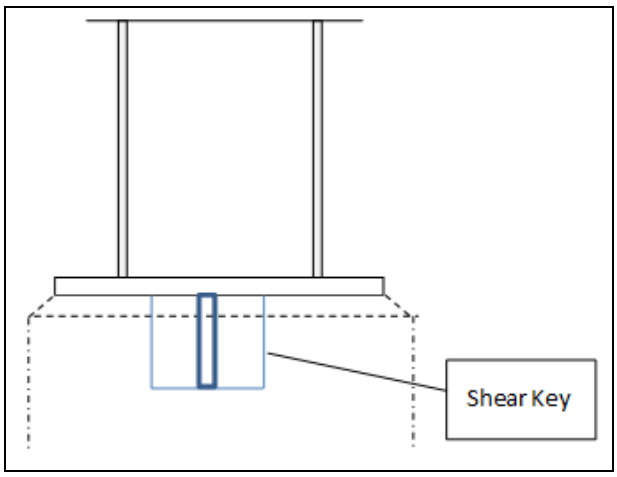
8. CONCLUSION

From above thesis report following conclusions has been drawn:-

1. Framed connections between pipe and pipe rack are suggested in all supports.
2. Through this thesis we tried to maximize the distance between supports keeping the value of stresses and deflection within safe limit.
3. 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.
4. The aim is to reduce the number of supports to reduce the total cost of erection.
5. Plan bracings are provided in K & L shape to resist lateral deflection and transfer the lateral load through vertical bracings.
6. This helps to reduce the size of the members and overall cost of the project.
7. Moment connections are considered on transverse bay above 9.0 m as large dia. pipes are rested on it.
8. Shear connections are provided in form of vertical bracings to disperse the shear force to the base.
9. Anchor bay is provided in each structure so, as to reduce the forces resulting in reduction of overall size of the member and thus, the total weight of steel sections is reduced.

10. Expansion loop is provided at every 60 m so as to resist the thermal expansion.
11. Vertical bracings are restricted upto 0.6 Interaction ratios, so as to reduce the connection design.
12. Vertical bracings are restricted upto 0.6 Interaction ratios, so as to reduce the connection design.
13. Base plates are grouped depending upon the generation of forces such as Compression, Tension & Shear forces.





Schematic of Base Plate & Shear Key

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