ANALYSIS AND DESIGN OF STEEL PIPE RACK - SUPERSTRUCTURE

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Major Project

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ABSTRACT

Petrochemical facilities have structures such as pipe rack, office building, steel shelters, and equipment support structure. Selection of structural steel pipe rack is done for study, as pipe racks are there in all types of industries for carrying pipe lines, electrical cable trays, PSV's etc.

Petrochemical plant layout for particular capacity is generalized and if another plant of same capacity is to construct at different location, than attempt is made that same layout can be used. As capacity and layout of plant are kept same than piping loads also remains same, the only change is in topography, which affects the design in respect of variation in wind speed and seismic zone. In majority of steel pipe racks as they are open frame structures, wind load with combination of piping load is governing, so here attempt is made to study effect of different wind speeds on pipe rack to develop template to start with preliminary design.

This report includes introduction to structural pipe racks, which further explains classification of pipe rack, applications of pipe rack, different loading and design considerations. To understand behaviour of pipe rack under different loads, one pipe rack having span of 48 m with five tiers and seven bays at spacing of 8m each has been model in STAAD Pro software, Different loading such as dead load (fireproofing, cable tray), live load, piping load (empty, test, operating condition), wind load and seismic load are applied. Analysis and Design has been carried out using Indian Standards.

In this piece of work, an attempt is made to study the behavior of structural steel pipe rack with structural modification which includes variation in section, using different bracing patterns such as K- Bracing, Knee bracing, diagonal bracing.

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ABBREVIATION NOTATION AND NOMENCLATURE

L	= Length (m)
A	= Cross section Area (mm^2)
I	= Moment of inertia (mm^4)
f	= safety factor
SF	= Shear force (kN)
BM	= Bending moment (kN m)
S	= spacing between lines (m)
B	= Width of flange
Ls	= spacing of intermediate beams
W_J	= Weight of joist per meter run
W_g	= Total weight of grating
W_{in}	= Instrument tray load
H_p	= Height of post
N_p	= Number of post
W_p	= Weight of each post
R	= Vertical load
W_{IL}	= Imposed load on walkway
C_f	= force coefficient
D_{min}	= Least overall frame dimension
n	= Number of frames
β	= Effective solidity ratio
η	= Shielding factor
σ_{ac} cal	= Actual axial stress(Mpa)
σ_{bc} cal	= Actual bending stress (Mpa)
σ_{ac}	= Permissible axial stress (Mpa)
σ_{bc}	= Permissible bending stress (Mpa)

1. INTRODUCTION

1.1 GENERAL

Structures are used in industrial facilities to support equipment and associated components to suit specific process and client requirements. An industrial structure is designed to support various types of equipments, pipes and those structures may be open or enclosed.

A pipe rack is mainly a part of process plant unit. Pipe racks carry process piping, utility piping and may also include instrument and electrical cable trays. They are necessary for supporting the process and service pipelines throughout the plant and is used in secondary locations for auxiliary equipment, pumps, utility station, and first aid station. Air-cooled heat exchanger (Air fin cooler) can be supported at top level of pipe rack. Pipe racks are long in length and located in the central zone of most plants, so pipe rack must be erected first, before it becomes obstructed by rows of equipment and other pipelines.

Typical cross section of pipe rack is as follows

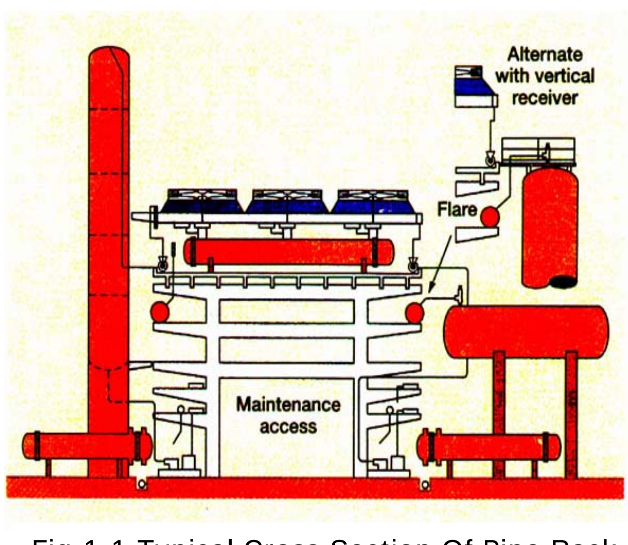


Fig.1.1 Typical Cross Section Of Pipe Rack

1.1.2 Definition

"A pipe rack is the structure used for carrying the pipe lines, electrical and instrument trays, which is usually constructed of steel or concrete frames called as bents on top of which pipe lines rests."

1.2 APPLICATIONS OF PIPE RACK

As mention above they are necessary for supporting the process and service pipelines throughout the plant and also to support following equipments:

1. Electrical trays are installed on pipe racks
2. Generally Air-fin cooler shall be located on the pipe rack.
3. PSV's are located on the pipe racks
4. Also used as secondary location for pumps, utility station, first aid station.

1.3 CLASSIFICATION OF PIPE RACKS

Pipe racks are mainly classified in three major categories depending on material used, location and geometry as follows

1.3.1 Material

1. Steel pipe rack
2. R.C.C pipe rack
   a. Precast.
   b. Cast in-situ
3. Combination of steel and R.C.C such as R.C.C for 1st tier considering fireproofing requirement and rest of above steel

1.3.2 Location

1. Process pipe rack
2. Interconnecting pipe rack
3. Road crossing pipe bridge
4. Flare pipe rack
5. Outside battery Limit (OSBL) pipe rack with or without AFC
6. Inside battery Limit (ISBL) pipe rack with or without AFC

1.3.3 Geometry

1. Single column.
2. Double column.
3. Multiple columns pipe rack.

1.4 INFORMATION REQUIRED FOR DESIGN OF PIPE RACK

1.4.1 Job Specification

Job specification contains design criteria affecting pipe rack design:

1. Battery limit, valve and space requirements.
2. Walkway, platform and ladder access to valves and relief valves in pipe rack.
3. Minimum headroom and clearances under overhead piping or supporting steel within areas
4. Access roads.
5. Standard to be used for minimum spacing of lines in pipe racks
6. Handling and headroom requirements for equipment positioned under pipe racks

1.4.2 Information Required For Basic Design

The following information shall be as a minimum include in loading data

1 Final pipe rack configuration – width, height, number of layer, columns spacing, intermediate beams, stair location

2 Preliminary piping layout, load and indication of intermediate beams

3 Preliminary location of longitudinal girder and supporting loads.

4 Preliminary location of pipe anchor and guide force.

5 Preliminary route of piping that crosses the pipe rack vertical bracing location

1.4.3. Information Required For Detail Design

All information mentioned in the basic information shall be fixed in the loading data and shall be the base of the detail design, additional information prior to commence detail design shall be as follows:

1 Location and load of trolley beam if any support location and load of miscellaneous equipment.

2 Information on additional/ deletion of longitudinal girders.

3 Insert plate location, size and load, and fixing bolt and base plate details of the equipment.

1.5 OBJECTIVE OF STUDY

Structures in petrochemical facilities are mostly design as open frame steel structures such as pipe racks, equipments support structure, etc. Pipe racks are selected for study, as they are required in each and every process plants to support piping. Petrochemical plant layout for particular capacity is generalized and if another plant of same capacity is to construct at different location, then attempt is made that same layout can be used. As capacity and layout of plant are kept same then piping loads remain same, the only change is in topography, which affects the design in respect of variation in wind speed and seismic zone.

In regards to wind loads, in majority of structures wind load with combination of piping load is governing.

Here in this study attempt is made to focus on variation in wind speed zone. With keeping others factors such as geometry, importance factors, terrain exposure, and gust factor fixed in order to provide a more consistent basis for comparison. Parametric study is carried out to study behaviour of pipe rack, considering variation in section property for main members and using different bracing pattern for vertical bracing.

1.6 SCOPE OF WORK

1.6.1 Phase I

1. Introduction to Pipe Racks
2. Literature survey
3. Theory of Pipe Racks.
    a. Classification on basis of material, location, geometry.
    b. Different types of loads on Pipe Rack and load Combinations.
    c. Structural arrangement of Pipe Racks
    d. Data required for basic and detail design and design consideration
4. Analysis and Design using STAAD Pro with IS code.
5. Result interpretation and conclusion.
    a. Impact of pipe loads on design.
    b. Governing load and load combinations.
6. References.

1.6.2 Phase II

1. Study behaviour of structural pipe rack under lateral loads
2. Analysis and Design with variation in wind speeds.
3. Parametric study considering structural modifications
4. Result interpretation and Conclusion.
5. References.

1.7 ORGANIZATION OF MAJOR PROJECT

The Introduction chapter starts with where, how and why pipe racks are used. It highlights the application, classification and information required for design of pipe rack followed by a topic of utmost importance, i.e. scope and objectives of the present study.

Chapter-2 includes the literature available and study done in past on petrochemical facilities especially on behaviour of industrial structure under lateral load such as wind loads or seismic loads.

Chapter-3 introduces, the basic guidelines required for structural arrangement of pipe racks right from the layout of process plant and best possible location of pipe rack in layout, further it focused on different loads on pipe rack.

Next chapter, i.e. **Chapter-4** includes problem formulation where input data for design of pipe racks is given in detail with loading with the help of which pipe racks has been design.

Chpater-5 gives detail analysis and design of pipe racks, which includes modeling of pipe rack in STAAD Pro, load calculation and STAAD output for analysis and design with support of manual check for design, chapter also focused on impact of various loads on design of pipe rack members.

Chpater-6, includes parametric study, considering variation in wind speed and structural modifications

Finally **Chpater-7**, gives summary and conclusion of the present work, which is followed by future scope of work.

2. LITERATURE REVIEW

2.1 GENERAL

This section includes, brief review of various books, papers, journals on the behavior of pipe rack in petrochemical facilities. The basic aim of literature review is to understand how pipe racks are model, analyze and their design philosophy.

2.2 ANALYSIS AND DESIGN OF PIPE RACK

Ed Bausbacher and Roger Hunt [1] Describes the basis concept of planning different components of process plant and piping design and planning of pipe supporting structure such as pipe racks.

Book explains what is required to finalize the pipe rack width, number of levels and elevations, and bent spacing and addresses pipe flexibility and maintenance concerns for each item located within the pipe rack area and also highlight the general requirements for structure layout. It covers the most common structural details and discusses equipment placement, maintenance and operational considerations.

John J. Mcketta [2] Focused on piping design and pipeline support design, in pipe line support design section it focused on design criteria which includes classification of types of support, criteria for selection of different support types, design loads on pipe racks with detail design procedure and sample calculation for wind and seismic load of two different geometry of pipe racks structure.

Hsieh-Lung Hsu [3] Study focused on seismic performance of equipment support structure with knee braced moment resisting frames in petrochemical facility construction. An attempt to integrate the ductile SMRF with knee braces at the beam column regions was made to improve the design efficiency, as well as the seismic performance. This integrated system is denoted knee braced moment resisting frames. The structural responses such as stiffness, strength, ductility and the economy level of Knee Braced Moment Resisting Frame (KBMRF) systems are function of the dimension of the applied knee braces.

The effects of knee braces on the structural stiffness, strength, and ductility were studied and quantified to define the feasibility of knee braces in the seismic design of such structures. It was found from parametric studies that frame stiffness increases when the magnitude (*eb*) and slope of knee brace (*ec* /*eb*) increase. For practical purposes, it is suggested that the *ec* /*eb* ratio be kept at 1 and *eb* less than 0.25 times the beam length. It was also observed that the maximum member forces in traditional SMRF shifted from the critical beam-column joints to the beam-knee-brace intersections, which greatly reduces the risk of brittle fracture at those regions and significantly enhances the ductility of these structures.

Marc Levitan[4] Represents the effect of Hurricane Winds on chemical plants, the facts that many of the structures found in the plants are not addressed by building codes and standards which has wide variations in design procedures and estimates of wind loads, even if the wind speed is specified. Most firms involved in the design or operation of chemical and petrochemical facilities developed their own wind loading guidelines. Here in this study designs guides for 13 major operating companies and engineering firms were obtained, Most of them used portions of ASCE 7 -02, mixed with bits and pieces from the British, Australian, and Canadian Codes

Wind loads on several sample structures were computed using all 13 design guides. The sample structures were located at a fictitious plant Lake Charles, Louisiana. Wind loads were computed on a fairly simple open frame structure. The structure was square in plan and 82 ft tall. The comparison was based on a 50-year MRI design wind speed, which corresponded to a peak gust of 120 mph.

SUMMARY

1. Some wind damage has been seen to occur during Category 3 and larger storms, but this information is not widely known.
2. Limitations of the codes and standards under which they plants were designed are not fully appreciated
3. Results of the comparison study for pipe racks yielded much greater variations, as much as 400% from the lowest estimate to the highest.

4. This is occurring at a time of increasing wind risk, especially to Louisiana plants, due to coastal land loss, long-term climactic trends of increasing Atlantic hurricane activity,

2.3 ASCE GUIDELINES [5]

This study shows that the state of the practice for the determination of wind loads on industrial structure is quite diverse. This specification provides guidelines with a commentary for wind load estimation on petrochemical structures as open frame structure and pipe racks,

Here comparison of different pipe and cable tray configuration were used to derive formula for wind load due to pipe and cable tray, according to study they have consider 5 different cases with different span of transverse girder and also variation in piping load

Wind on the pipe rack structure itself should be calculated on based on shielding, for all structural members C_f - 1.8, or alternatively C_f **=** 2.0 for members above the first level.

TRIBUTARY AREA FOR PIPING

The tributary area for piping should be based on the diameter of the largest pipe plus 10 % of the width of the pipe rack. This sum is multiplied by the length of the pipes to determine the tributary area.

3. GUIDELINES FOR STRUCTURAL ARRANGEMENT OF PIPE RACK

3.1 PIPE RACK LAYOUT [6]

The first step in the development of pipe rack is the generation of a line routing diagram, a line routing diagram is schematic representation of all process piping system drawn on a copy of the plot plan, Although it disregards exact location elevations or interference. With the receipt of engineering flow diagrams and utility flow diagrams, a more complete and accurate assessment of rack space is possible. Utility headers generally run the whole length of the pipe rack, so headers should be taken into account when estimating additional space required. Piping economy depends primarily on the length of lines routed in the pipe rack. Below figures shows overall plant layout.

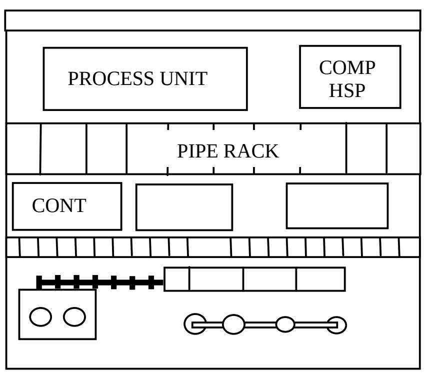


Fig 3.1 Straight Pipe Rack Line

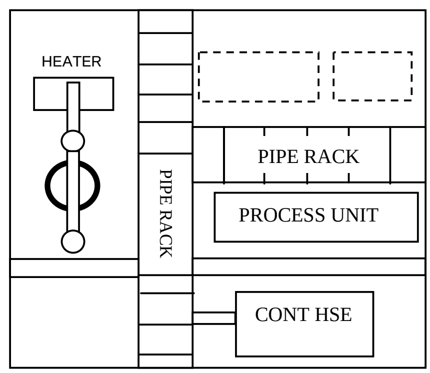


Fig 3.2 “T” Shape Pipe Rack

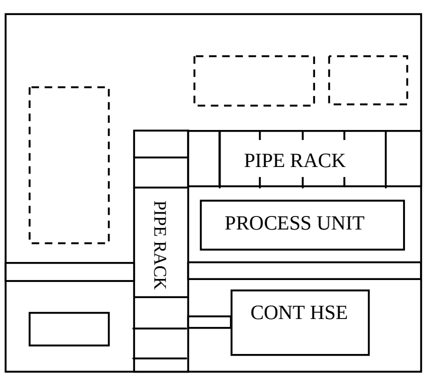


Fig 3.3 “L” Shape Pipe Rack

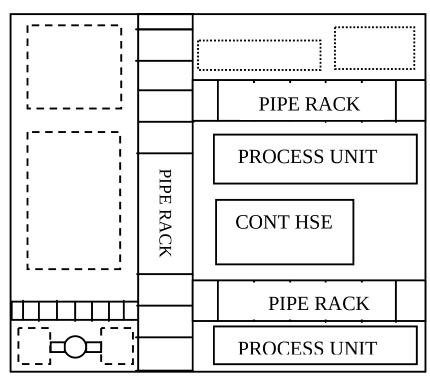


Fig 3.4 Combine “L” &“T” Shape Pipe Rack

3.1.1 Process Flow Diagram

Process flow diagrams show main process lines and lines interconnecting process equipment.

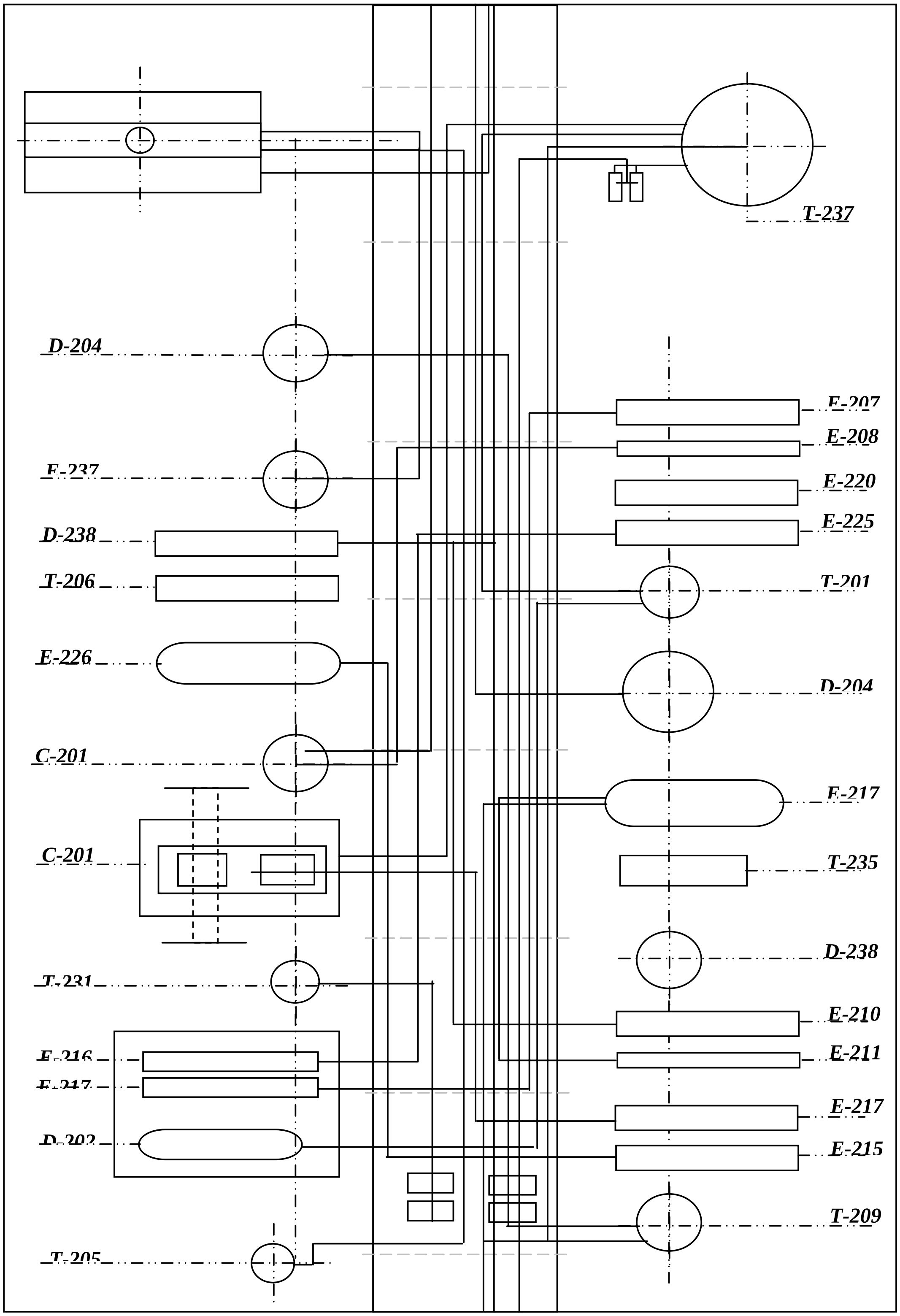


Fig 3.5 Line Routing Diagram

Process flow diagram provides insight to operation temperatures and identifies the need for insulation. Once the routing diagram is complete the development of rack width, bent spacing and numbers of levels and elevation may proceed.

3.1.2 Pipe Rack Bent

A pipe bent consists of a vertical column or columns and a horizontal structural member or members that carry piping systems, usually above headroom. Pipe racks are customized to a specific plant, pipe size in chemical plants are smaller than those found in refinery units. If a plant requires 4.9 m spacing, the variation allows for 9.7 m spacing by adding intermediate bents supported from spandrels.

Normal spacing between pipe rack bents varies between 4.6m to 6m, this may be increased to a maximum of 8m but consideration must be given that smaller line which must be supported more frequently, liquid filled lines requiring shorter span than gas filled lines, hot lines which span shorter distances than cold lines of the same size and wall thickness, insulated lines due to weight of insulation must be supported at relatively short intervals and space requirements of equipment at grade can sometimes influence pipe rack bent spacing.

3.1.3 Pipe Rack Width

Width of pipe rack is influenced by:

1. The number of lines
2. Electrical/instrument cable trays.
3. Space for future lines.

The width of a pipe rack may be calculated using the following method, First estimate number of lines as described. Add up the number of lines up to 450 mm diameter in the densest section of the pipe rack.

Than the total width in meters (W) will be

$$W = (f \times N \times S) + A \quad (m)$$

Where f, safety factor = 1.5,

N = Number of lines below 450 mm diameter

S = Average estimated spacing between lines (mm)

S = 300 mm

S = 230 mm (if lines are smaller than 250 mm)

A = additional width required for :

a) Lines larger than 450 mm.

b) Future lines.

c) Instrument and electrical cable trays.

If W is bigger than 9m usually two pipe rack levels will be required. At the beginning of a design, ‘W’ should usually include 30 - 40% of clear space for future lines. Below figure shows typical pipe racks bents with tabulated dimensions.

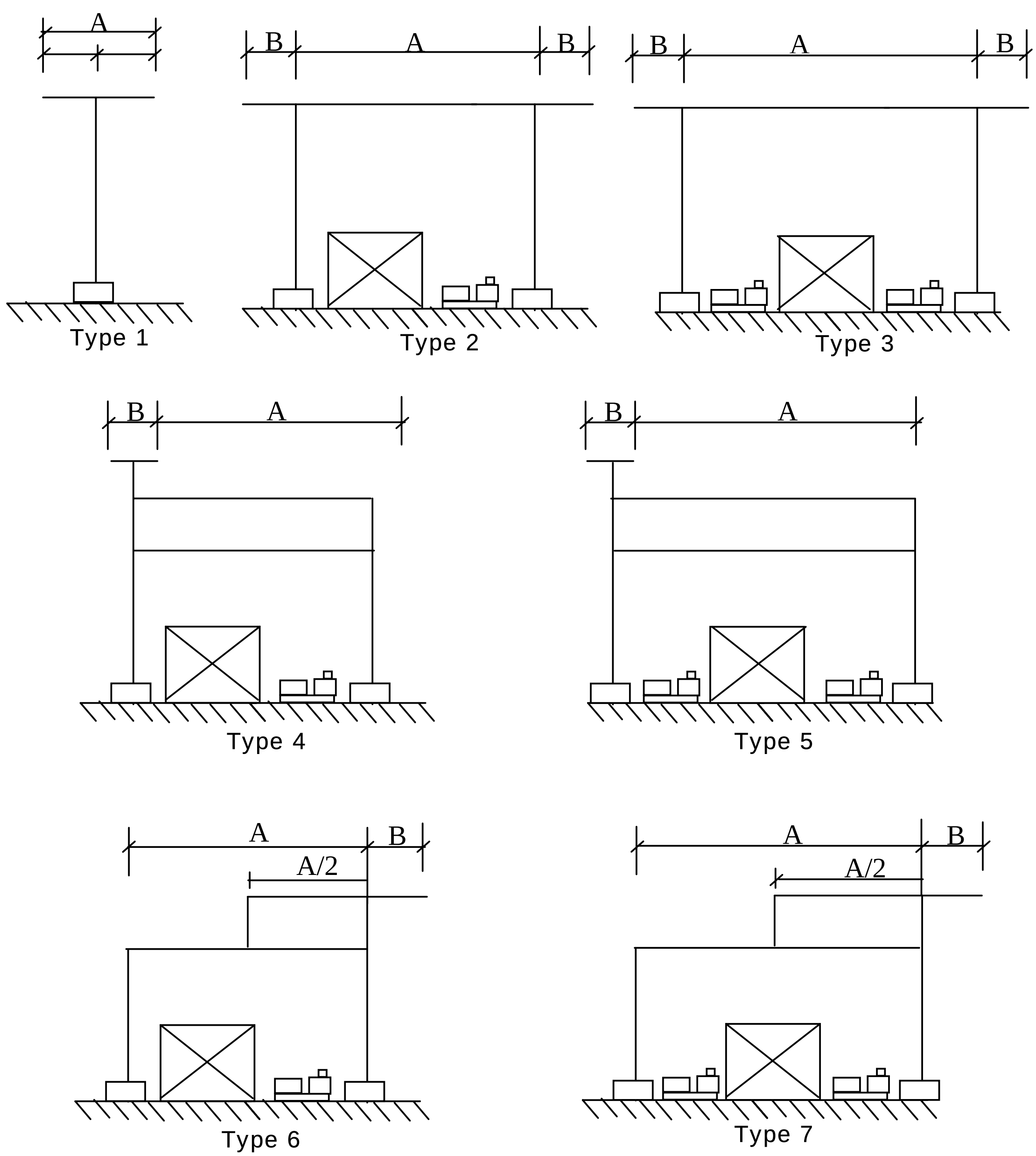


Fig 3.6 Typical Pipe Bents Sections

Table 3.1 Typical Pipe Bents Dimensions

Type No	Total Available width w (m)		Pipe rack Width (A)	Cantilever Width (B)	Number of tiers
	Without Cantilever	With Cantilever			
1	3.0	-	3.0	-	1
2	6.0 TO 7.3	9.15 TO 10.4	6.0 TO 7.3	1.5	1
3	8.5 TO 9.7	11.6 TO 12.8	8.5 TO 9.7	1.5	1
4	11.9 TO 14.3	13.7 TO 16.1	6.1 TO 7.3	0.9 OR 1.2	2
5	16.8 TO 19.2	18.6 TO 21.0	8.5 TO 9.7	0.9 OR 1.2	2
6	8.5 TO 10.4	11.0 TO 12.8	6.1 TO 7.3	0.9 OR 1.5	1.5
7	12.2 TO 13.4	14.6 TO 15.8	8.5 TO 9.7	0.9 OR 1.5	1.5

3.1.4 Pipe Rack Elevation

Pipe rack elevation is determined by the highest requirement of the following:

1. Headroom over main road
2. Headroom for access to equipment under the pipe rack
3. Headroom under lines interconnecting the pipe rack and equipment located outside.

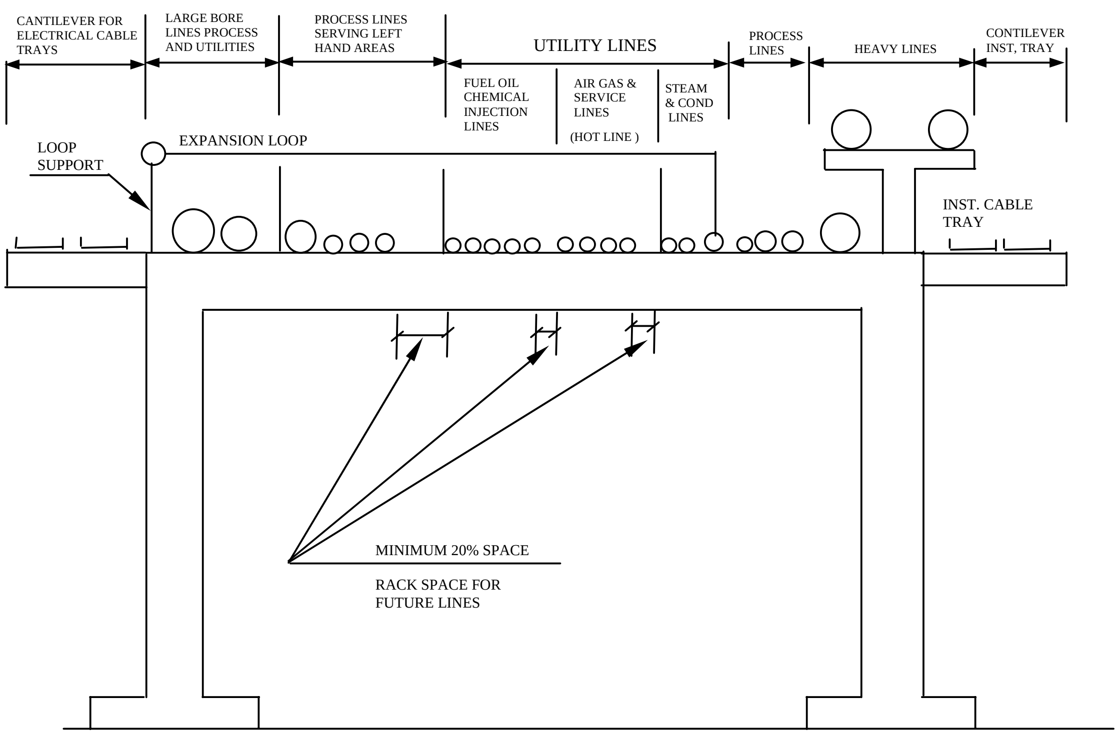


Fig 3.7 Detail Cross Section Of Pipe Rack

3.2 STRUCTURAL ARRANGEMENT OF PIPE RACK [6]

3.2.1 Column

1 Column's strong axis shall be oriented to the transverse direction (normal to piping layout) for efficient resistance to bending moment and lateral displacement.

2 In principle for economical design, no bending moment shall be subjected to column section about its minor axis. A braced framing system in the longitudinal direction of pipe rack can be applied to attain this philosophy.

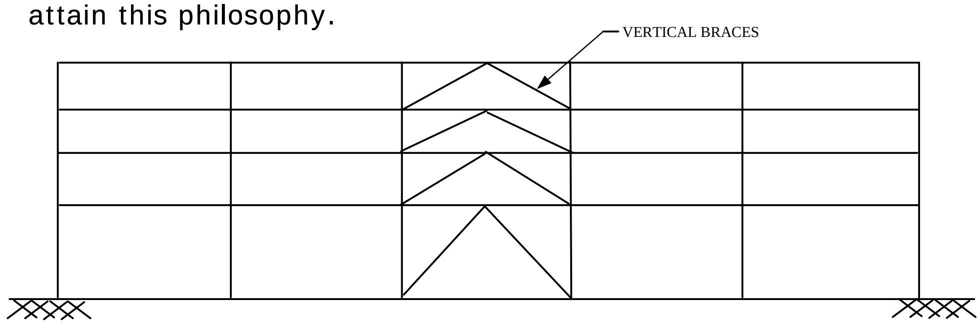


Fig 3.8 Braced Framing System in Longitudinal

3.2.2 Girder And Beam

1 Beams (transverse, intermediate and longitudinal) shall be installed at the location where required by piping loading data

2 Small piping and cable duct, which requires sub beam in pipe rack, shall be installed at the same layer.

3 In case of steel members, flange width "B" of the beam for

4 L/B ratio is assume as:

a) Flange width "B" of girder is assumed from "L/B=35 ~40."

b) Flange width "B" of longitudinal beam is assumed from

L/B = 40 ~ 45

c) Flange width "B" of sub beam is assumed from L/B = 40 ~ 45.

d) Flange width "B" of beam where the horizontal force acts on weak axis of beam is assumed from "L/B = 30 ~ 35".

3.2.3 Vertical Brace

1 V- shape of vertical brace is used as typical, and X- shape may be also used where no objection for access under pipe rack or slenderness ratio of brace member is acceptable.

2 Vertical brace in longitudinal direction of pipe rack shall be located at the center bay of the pipe rack as shown in fig 3.8.

3 In case that vertical braces along longitudinal direction are provided in more than 2 bracing panels, and each bracing panel is located far to one another, attention shall be paid for the large stress due to thermal expansion of pipe rack.

3.2.4 Horizontal Brace

Except for the following case, horizontal brace shall be provided minimal, because it can cause interference with piping route.

1 Large horizontal force due to piping anchor acting on the support beam.

2 Beam span in longitudinal direction is more than 10m.

3 Location required long span, and to keep the rigidity in horizontal direction.

4 Location to support the heavy weight or vibrating equipment.

5 Location to support the vibrating load of piping.

6 Where no rigidity in horizontal direction assumed and grating stage.

7 Location of cantilever beam with long span for monorail.

8 X-shape of cantilever brace is used for typical, and square shape can be also used in case of slenderness ratio is large.

3.2.5 Strut

1 Strut shall be located at the center of span more than 6.0m

2 Strut shall be installed to reduce minor axis bending moment on beam due to horizontal thermal force

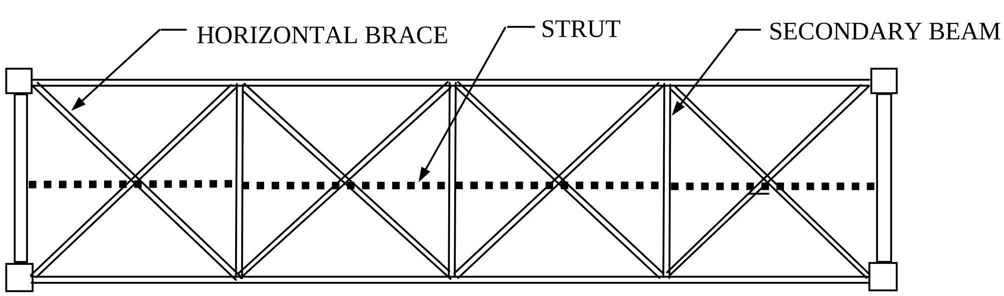


Fig 3.9 Typical Pattern of Horizontal Brace & Strut

3.2.6 Knee Brace

1. Knee brace shall be installed to prevent the large size of frame member (shown in fig 3.11), where story height is large and is disadvantages for vibration and small displacement.
2. Uneconomical design of frame member will be avoided, when knee brace is used to reduce member span subjected to applied loads thus, bending moment and deflection will be reduced as well.

3.2.7 AFC And Header Support

1. In addition to the structure to support Air Fin Cooler, piping support for AFC header discharge and inlet may also be required depending on the number of bundles in AFC and piping requirements.
2. Support of AFC header piping shall be selected in principle, the type supported by piping nozzle.
3. Rigid frame shall be applied in direction at right angle crossing the header piping, however when no interference with piping is confirmed, brace or knee may be used.
4. Braced frame shall be applied in parallel direction with header piping.
5. Usually RCC floor are provided at top of pipe rack to prevent hydrocarbons being sucked by AFC fans.

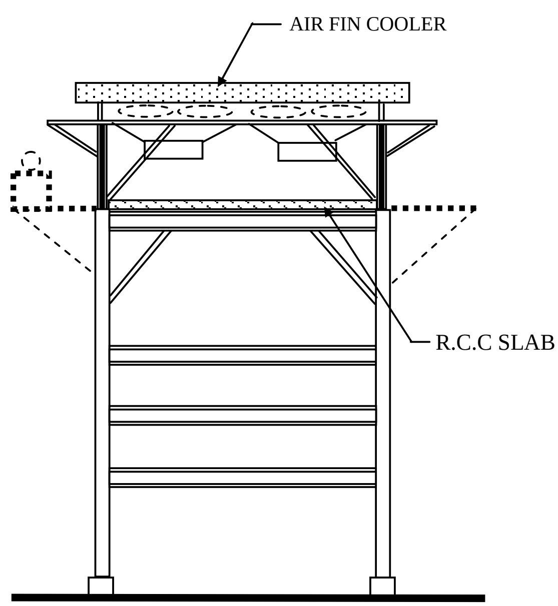


Fig 3.10 AFC Mounted on Pipe Rack

3.2.8 Stage and Walkway

1. Stage and walk way on pipe rack shall be arranged depend on layout, and make it simple as much as possible.
2. Head clearance between stage and beam above shall be complied with project specification.
3. Inclination or slope on stage shall be provided for flow, when the drainage is required.

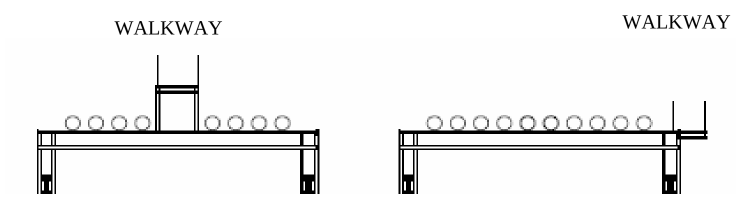


Fig 3.11 Pipe Racks With Walkway

3.2.9 Stairs and Ladder

1. Stair supporting beam shall be arranged as cantilever beam attached to column.
2. Staircase with framed structure will be provided, when long support required or heavy weight designed.
3. Slope, rise, tread and pitch of landing shall be designed in accordance with the project specification.
4. Head clearance above stair with brace or beam shall be kept in accordance with the project specification.

3.3 LOADS ON PIPE RACK

3.3.1 Dead Load

Dead load of small stage, about 1 m in height and placed on the floor of pipe rack, is taken as follows:

1. Without handrail: 1.2 kN/m^2
2. With handrail: 1.5 kN/m^2
3. Self weight of fireproofing
4. Duct trays load

3.3.2 Live Load

It shall be check if the load on the floor during a maintenance condition is within the live load for general floor. If it exceeds the general live load, the structure shall be designed on the maintenance load.

When the value for live load is different between the maintenance floor and walkway, the extent of each area shall be checked and confirmed.

3.3.3 Piping Load

All pipes with diameter less than 12" shall be treated as uniform load, in order to prevent the complication of calculation. All larger pipes shall be treated as concentrated load. Usual piping load of pipe rack is varied from 0.8 to 2.5 kN/m^2 according to the type of plant. The estimated piping weights based on the diameter and spacing are as follows:

a) Piping load arranged with 6 inch piping at the 450 mm pitch.

SCH – 40: 1 – 1.2 kN/m^2, SCH – 80: 1.3 –1.5 kN/m^2

SCH 160: 1.8 – 1.9 kN/m^2

b) Piping load arranged with 4 inch piping at the 300 mm pitch

SCH – 40: 0.9 – 1.0 kN/m^2, SCH – 80: 1.1 –1.2 kN/m^2

SCH - 160: 1.4 – 1.5 kN/m^2

1. Locations and loads for control valve sets placed on the floor around equipment shall be checked and confirmed carefully. Generally, a test load for piping is carried out with full water condition, but testing shall not be carried out at same time.
2. The thermal forces (anchor, guide and friction) direction, magnitude and period of existences (short or long term) shall be confirmed from the piping group
3. Unless otherwise specified in the project specification, friction force due to thermal expansion of piping shall be considered only for the design of beam directly supporting the piping load and not to be considered in the frame member design (girder, column and foundation)
4. Piping shaking/ impact load and location due to vibrating equipment such as compressor and pump shall be confirmed from the piping group.
5 Piping can be supported on longitudinal beam of pipe rack and only piping load greater than 10 kN will be shown in loading data in other

case loading member size for longitudinal girder shall be capable to sustain a minimum load of 10 kN.

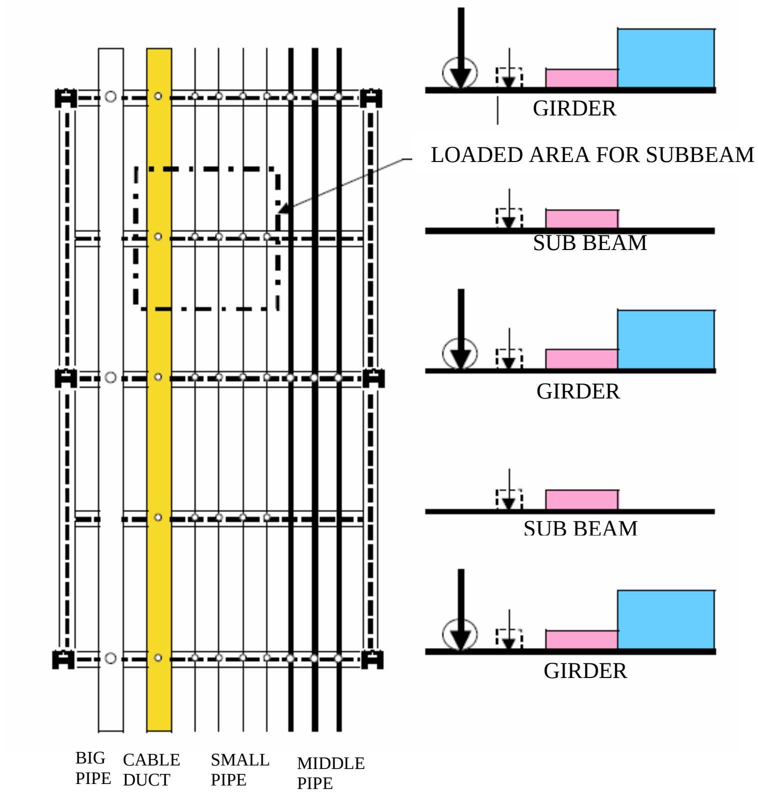


Fig 3.12 Piping Load On Pipe Rack

3.3.4 Equipment Load

1. Equipment load for AFC varies from 6.0 to 8.0 kN/m2,
2. The hydrostatic testing for equipment shall be confirmed whether testing is to be carried out at the shop or the site.

3.3.5 Monorail Load

Capacity of monorails shall be checked. The load shall include the weight of hoist and the impact load shall be computed according to the design criteria.

3.3.6 Wind Load

3.3.6.1 Wind Load On Pipe Rack

Shape coefficient and number of frames to be included in computation of wind load for the framing shall be according to the design criteria. When the number of frames to be included in wind load computation is not specified in the design criteria, only one frame facing wind direction shall be considered.

3.3.6.2 Wind Load On Piping

Unless otherwise specified in the project specification, wind load acting normal to the piping shall be considered for one large sized pipe at each elevation

3.3.7 Seismic Load

Seismic force shall be computed according to the design criteria further given in chapter 4

4. PROBLEM FORMULATION

4.1 GENERAL

This chapter briefly outlines the design criteria for loads, load combinations, materials & analysis used for design of Pipe Rack. Pipe rack along grids L & M between grids 1 to 21 (refer appendix A) has been designed in three stretches of 48m each i.e. from grids 1 to 7, from grids 8 to 14 and from grids 15 to 21. Expansion joint between grids 7 & 8 and between grids 14 & 15 isolates the stretches completely. For loading from piping appendix A should be refer.

4.2 DESIGN CRITERIA AND SPECIFICATIONS

The design of Pipe rack is in accordance with the following codes and standards.

1. IS 456: 2000: Indian Standard Code of Practice for Plain and Reinforced Concrete.
2. IS 800: 1984: Indian Standard Code of Practice for General Construction in Steel.
3. IS 875 (Part 3): 1987: Indian Standard Code of Practice for Design loads (other than Earthquake) for buildings and structures. (Wind Loads)

4.2.1 Analysis and Design

Pipe racks are analyzed in 3D models using STAAD Pro.

4.2.2 Connection Type

Member	X-Direction	Z-Direction
Column base	Pinned	Fixed
Beams	Pinned	Fixed

Longitudinal beams shall be vertically braced preferably between piping anchor supports

4.3 MATERIALS OF CONSTRUCTION

Entire superstructure shall be of Structural steel.

1. Structural Steel : Conforming to IS:2062 ; f_y = 250 Mpa.
2. Weld : Conforming to IS 816
3. Bolts : Conforming to IS 1367- 1980, Property class 8.8
4. Cement : OPC/PPC
5. Lean Concrete : Nominal Mix 1:5:10
6. Structural Concrete: f_{ck} = 35 MPa (min 400 kg/cum)
7. Reinforcing bar : f_y = 415 MPa conforming to IS : 1786

4.4 TYPE OF LOADING

4.4.1 Dead Loads: (D)

1. Appropriate densities are defined for the structural members from which their self weights are automatically generated by STAAD Pro.
2. Additional weights of fire-proofing are considered.
3. Electrical and Instrumentation cable loads along with the tray/duct supporting systems are considered as supplied by the respective departments.
4. Weight of walkways and platforms along with grating are considered.

4.4.2 Imposed Loads: (L)

Imposed loads are considered as follows :

1. Walk ways : 2.50 kN / m^2
2. Platforms for Valve Operations : 5.00 kN / m^2
3. Stairways : 2.50 kN / m^2

4.4.3 Piping Loads: (P)

Piping Loads on Pipe supporting members for :

P(E) Empty Condition (Refer Appendix A)
P(O) Operating Condition (Refer Appendix A)
P(T) Test Condition (Refer Appendix A)

All the types of Pipe Loading (Vertical & Horizontal) shall be considered as per Input from Piping Department (Pipe Rack Loading Data Sheet).

Piping Load on Longitudinal Beam : Piping load for P(E), P(O) & P(T) considered as 25 % of loading on Transverse beam applied as two concentrated load acting at 1/3 span.

Piping Load on Intermediate Transverse Beams at tier level: It is considered as 25 % of design udl on main Transverse beam for respective load case i.e P(E), P(O), P(T).

4.4.4 Thermal Friction & Anchor Forces: (T)

The friction force at each tier on every portal both in longitudinal and transverse directions is considered 10% of the design vertical loading of the pipes. Longitudinal friction force is considered as uniformly distributed over the entire span of the beam at each tier and transverse friction force is considered as a concentrated load at each tier level. Friction force at Flare Header support is taken as 30% of the vertical loading. Both longitudinal and transverse friction forces shall be considered to be acting simultaneously.

(For Anchor Load please refer Appendix A)

4.4.5 Wind Load: (W)

Wind loads are calculated as follows:

Basic Wind Speed = 50 m/ Sec

K1 = 1.0

K2 = Factor for relevant class of the structure with Category-3 terrain.

0.88 (for Class B and height up to 10m)

0.94 (for Class B and height 10m to 15m)

K3 = 1.0

Wind Load Z Dir: Transverse Wind Force (N) at each tier Level is taken as 2.0x p_z x s (For Pipe rack Width = 8m)

Where p_z = Design Wind pressure (N/sqm)

s = Spacing of Portals (m)

Wind Load X Dir : Wind load in Longitudinal direction is considered as per exposed area of frame in longitudinal direction depending on solidity ratio, frame spacing ratio and shielding factor is as per IS 875 provisions and is applied as a concentrated load at a joint.

4.4.6 Earthquake Force: (V)

Earthquake Force is considered as per Seismic Coefficient method in accordance with IS: 1893 with the following parameters:

Zone	z	:	III
Importance factor	I	:	1.5

4.5 LOAD COMBINATIONS

Load combinations for member design shall be as follows :

Load Condition	Load combination
Erection	[D+L+P(E)]
	[D+P(E)+W]
Maintenance	[D+P(E)]
Operating	[D+L+P(O)+T]
	[D+L+P(O)+T]+[W or V]
Test	[D+L+P(T)]
	[D+L+P(T)]+[25%W]

4.6 SPECIAL PROVISIONS

4.6.1 Type and Extent of Fireproofing

Fire proofing is done up to EL 109.100 (30 ft from GL) in all the bays for all load carrying members and vertical bracing members as per OISD 164 in normal weight concrete as per project specification. Vertical bracing which resists lateral forces only due to wind/seismic, may not be fireproofed.

4.6.2 Increase in Stresses

For members of structure designed by Allowable stress method, for load combinations with short term loads (viz. Wind or Earthquake), increase in stresses shall be as per relevant IS Codes as follows:

33.33% of increase in stress will be allowed for structural steel members.

25% increase in stress will be allowed in bolts and welds.

5. ANALYSIS AND DESIGN OF PIPE RACK

5.1 GENERAL

This chapter focused on structural modeling, analysis and design of pipe rack. Analysis and design of pipe rack is carried out in STAAD Pro software.

5.2 STRUCTURAL MODELING OF PIPE RACK

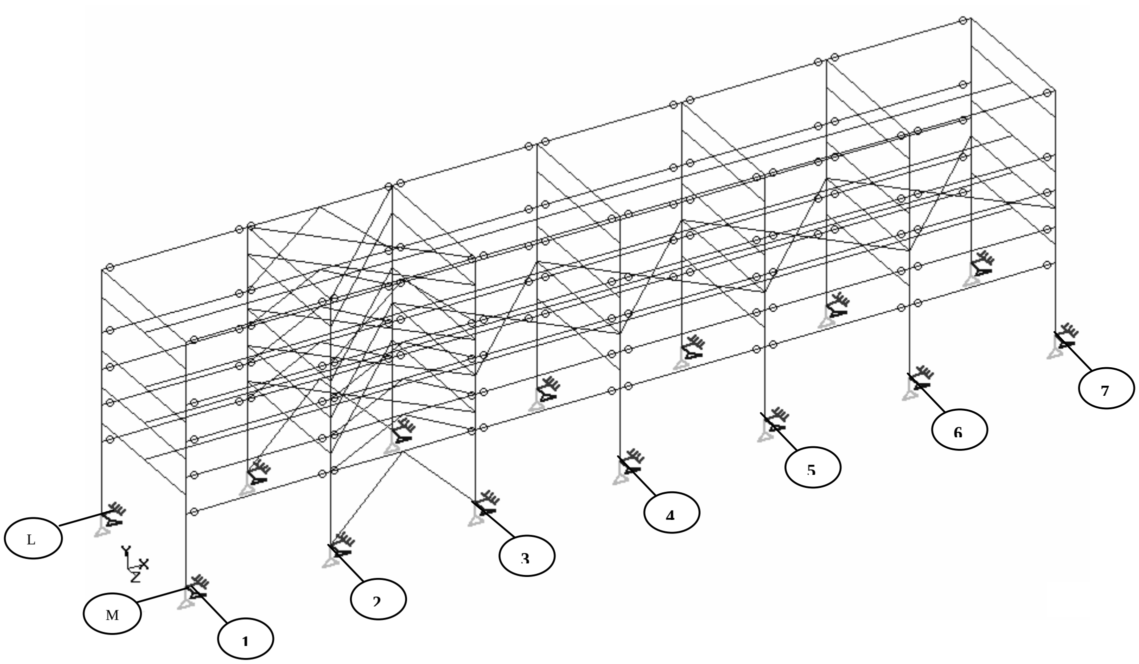


Fig 5.1 Model of Pipe Rack in Staad Pro

1. As shown in fig 5.1, 3D model of pipe rack in STAAD Pro with grid L and M in transverse direction and grid 1 to 7 in longitudinal direction.

2. Support conditions are as follows:

Member	X-Direction	Z-Direction
Column base	Pinned	Fixed
Beams	Pinned	Fixed

3. Pipe racks are usually designed with special moment resisting frames (SMRF) in the stronger direction to allow operational facility and maintenance equipment access, and the placement of main piping.

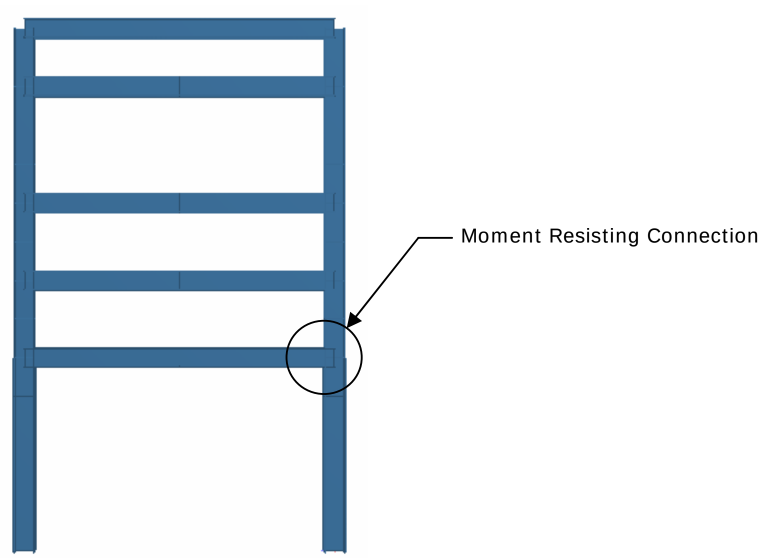


Fig 5.2 Transverse Frame with Rigid Connections

4. The weak structural directions, on the other hand, are usually designed with braced frames due to stiffness concerns and less access requirements. The braced frames are effective structural forms for providing stiffness.

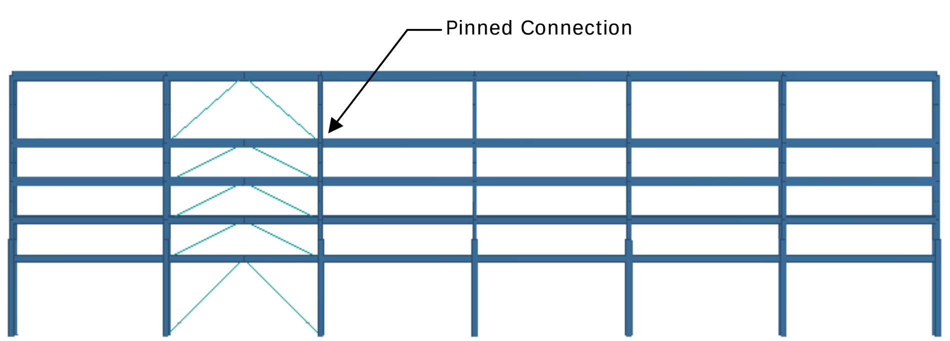


Fig 5.3 Longitudinal Frame with Pinned Connections

5. Vertical and plan bracings are provided as double angle as given in Table 5.1 and are define as truss members in STAAD Pro.

6. As shown in Appendix A, anchor forces are applied at bay number 5th as it is define as anchor bay, and usual practice is that anchor bay should be braced

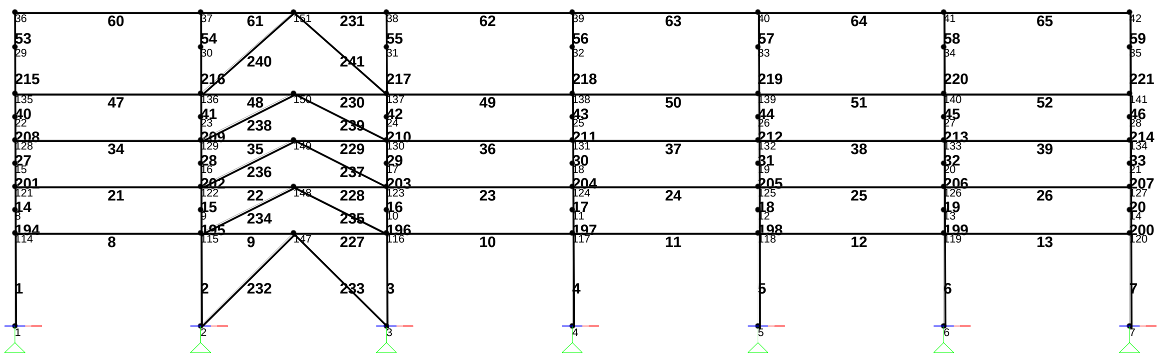
but as most of the piping is coming in at same bay so bracings in longitudinal direction is provided at 2nd bay.

7. Bracings in plan are provided at 107.00 m level and model as truss members.

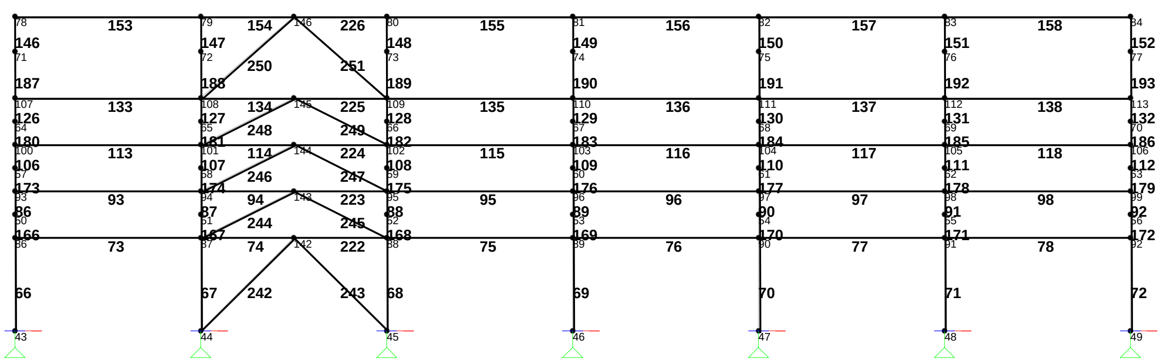
8. Secondary beams has not been model in staad, but their reaction has been transferred to main beams

5.2.1 Member and Node Numbers

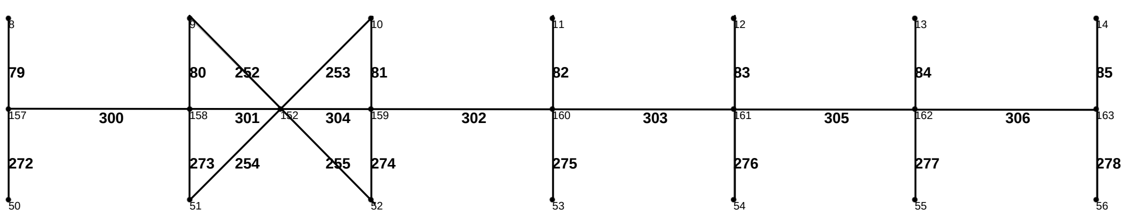
Following figures shows member and node numbers.



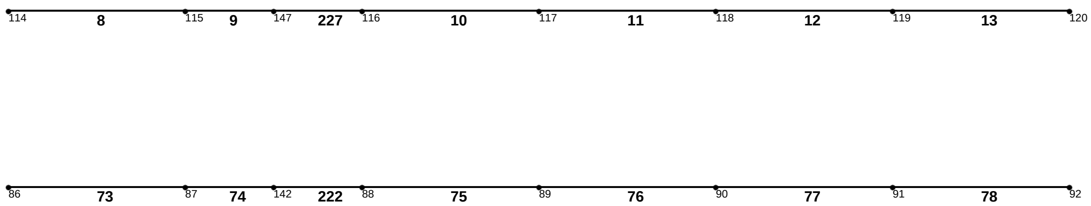
A. Grid L



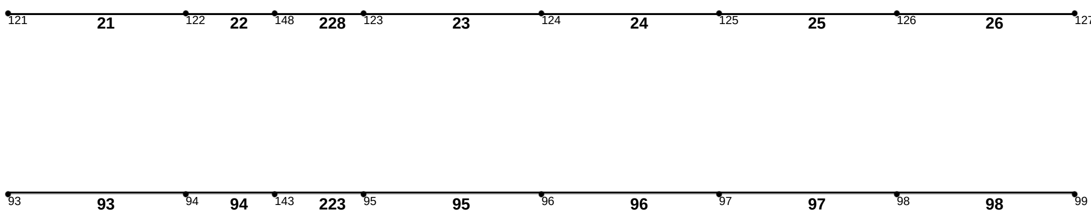
B. Grid M



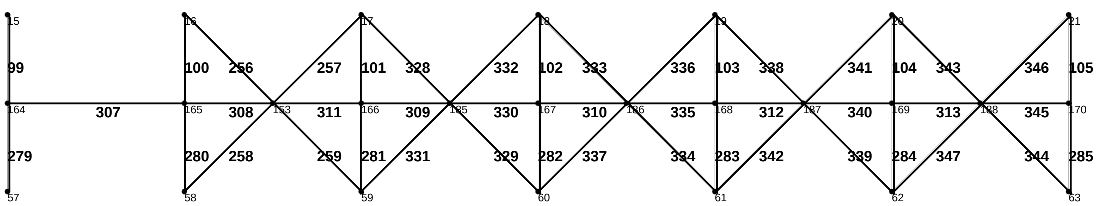
C. Level 104.00 m



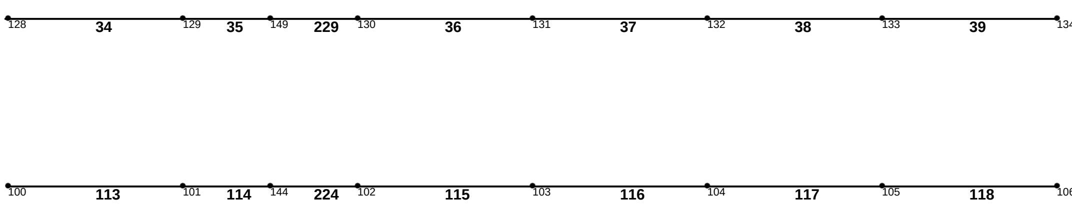
D. Level 105.00 m



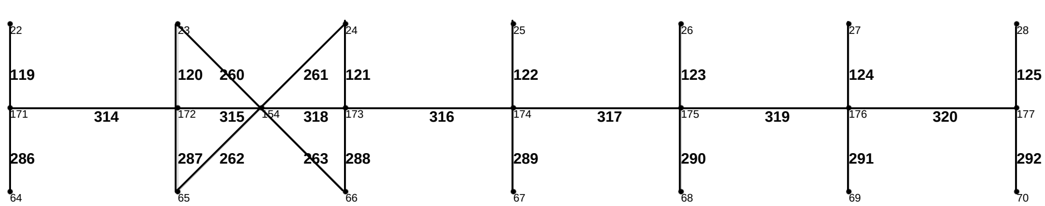
E. Level 106.00 m



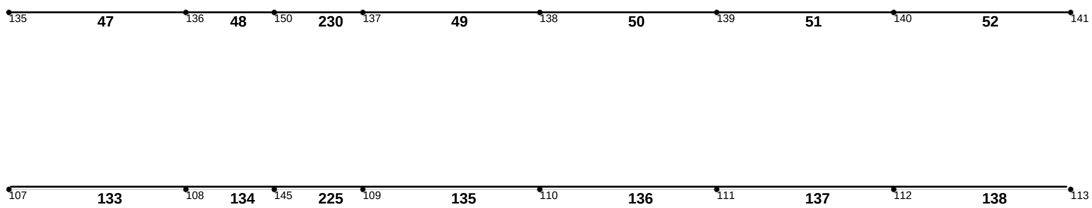
F. Level 107.00 m



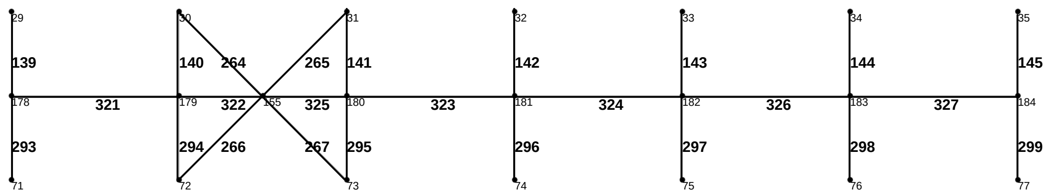
G. Level 108.00 m



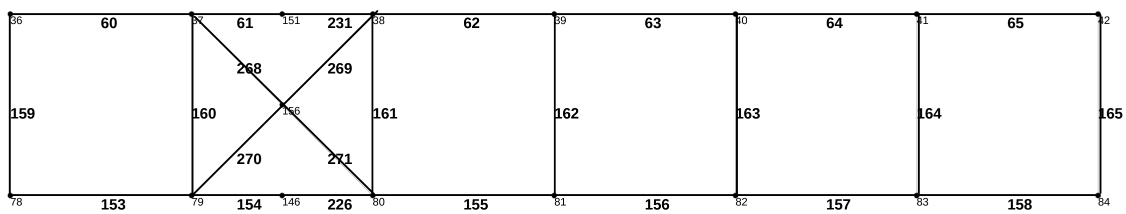
H. Level 109.00 m



I. Level 110.00 m



J. Level 112.00 m



K. Level 113.50 m

Fig 5.4 Member and Node Numbers

5.2.2 Member Definitions

Member definitions for analysis of different components are as follows:

Table 5.1 Member Definitions

MEMBER	SIZE
Columns	Columns ISMB500 + 250 x 12 mm plate (T/B)
	ISMB500
Transverse Beams	ISMB500
Longitudinal Beams	ISMB300
Plan Bracings	Double Angle ISA75x75x8
Vertical Bracings	Star Angle ISA110x110x12
	Star Angle ISA100x100x10
Struts	Double Angle ISA75x75x8

5.3 LOAD CALCULATION

5.3.1 Dead Load and Live Load

5.3.1.1 Fireproofing Load

Fireproofing weights for different sections are considered as follows:

Thickness of fireproofing = 50 mm

Density of fireproofing concrete = 24 kN/m^3

Profile fireproofing consider for depth of section greater then 300 mm

Table 5.2 Fireproofing Weights for Different Sections

Member	No. of Sides Fireproofed	Section	Fireproofing Weight (kN/m)
Column	4	ISMB 500 + 250 X 12 mm thk plate	2.434
Column	4	ISMB 500	2.29
Long. Beam	3	ISMB 450	1.72
Long. Beam	3	ISMB 400	1.57
Long. Beam	3	ISMB 300	1.89
Transv. Beam	3	ISMB 500	1.95
Transv. Beam	3	ISMB 400	1.57
Inter. Portal Col.	4	ISMB 300	2.17
Inter. Portal Beam	3	ISMB 300	1.89
Vert. Brace	4	2ISA 100X100X10 STAR	1.93
Vert. Brace	4	2ISA 110X110X12 STAR	2.434

5.3.1.2 Dead Load from Walkway

Width of walkway B = 0.9 m

Spacing of intermediate beams Ls = 2.7 m

Size of joist = ISMC100

Weight of joist per meter run w_j = 9.2 kg/m

Total weight of both joists W_j = 2 x w_j x L_s

= 49.68 kg

Weight of grating w_g = 50 kg/m^2

Total weight of grating W_g = W_g x L_s x B

= 100.80 kg

Weight of handrail	w_h	=	4 kg/m
Total weight of both handrails	W_h	=	$2 \times w_h \times L_s$
		=	40 kg
Total weight of walkway	W_w	=	$W_j + W_g + W_h$
		=	232.80 kg
		=	2.328 kN

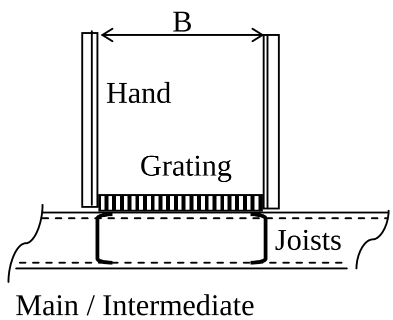


Fig 5.5 Details of Walkway

5.3.1.3 Instrument Cable Duct

a. For Grid 1 to 4

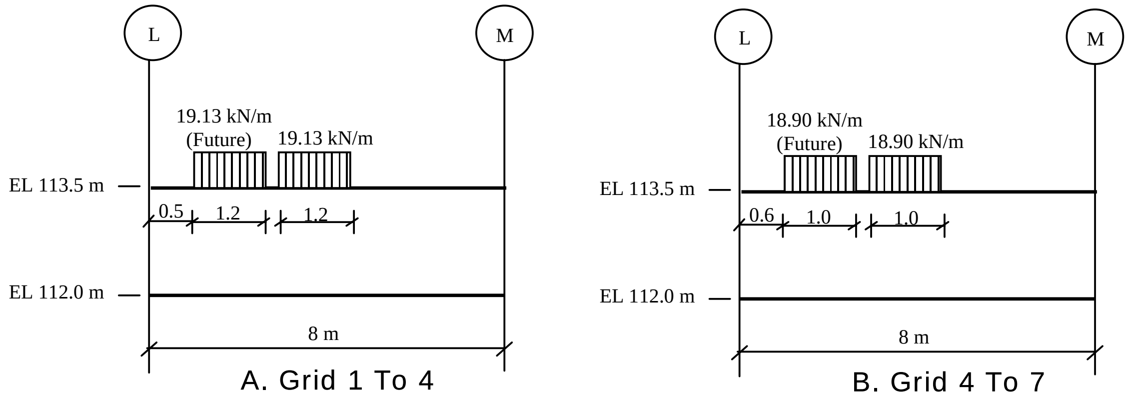
Instrument tray load on main & intermediate transverse beams

Weight of instrument tray per meter run	W_{in}	=	8.50 kN/m
Width of instrument tray	b	=	1.20 m
C/C distance between supports of tray	L_t	=	2.70 m
udl on each supporting beam		=	$W_{in} \times L_t / b$
		=	8.5 x 2.7/1.2
		=	19.125 kN/m

b. For Grid 4 to 7

Instrument tray load on main & intermediate transverse beams

Weight of instrument tray per meter run	W_{in}	=	7.00 kN/m
Width of instrument tray	b	=	1.00 m
C/C distance between supports of tray	L_t	=	2.70 m
udl on each supporting beam		=	$W_{in} \times L_t / b$
		=	7 x 2.7/1.0
		=	18.90 kN/m



A. Grid 1 To 4 B. Grid 4 To 7

Fig 5.6 Cable Tray Loading

5.3.1.4 Cable Tray Supports

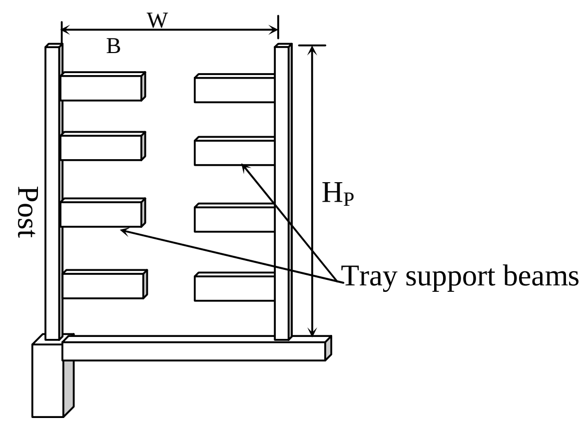


Fig 5.7 Details of Cable Tray

a. POST

Height of post	H_p	=	1.300 m
Nos. of posts	N_p	=	2 Nos.
Size of post		=	ISMC100 BOX
Weight of post / RM		=	18.400 kg/m
Weight of each post	W_p	=	0.239 kN

b. TRAY SUPPORTING BEAM

Length of tray supporting beam		=	0.850 m
Nos. of beams on post P_1		=	4 Nos.
Nos. of beams on post P_2		=	4 Nos.
Size of beam		=	ISMC75
Weight of beam / RM		=	6.800 kg/m
Weight of beams on post P_1	W_{b1}	=	0.231 kN

Weight of beams on post P_2 W_{b2} = 0.231 kN

c. CABLES

Weight of cables per tray/ RM = 75.00 kg/m

Longitudinal dist. between posts = 2.650 m

Weight of cables on post P_1 W_{c1} = 7.950 kN

Weight of cables on post P_2 W_{c2} = 7.950 kN

Vertical load at bottom of P_1 R_1 = $W_p + W_{b1} + Wt_{b1} + Wl_{b1} + W_{c1}$

= 0.2392 + 0.2312 + 0 + 0 + 7.95

= 8.420 kN

Vertical load at bottom of P_2 R_2 = $W_p + W_{b2} + Wt_{b2} + Wl_{b2} + W_{c2}$

= 0.2392 + 0.2312 + 0 + 0 + 7.95

= 8.420 kN

5.3.1.5 Walkway At Level 113.50

Width of walkway B = 1.0 m

Spacing of main beams Ls = 8.0 m

Weight of supporting members is as follows

Joists (ISMC 75 @ 6.8 kg/m) = 0.068 x 1.0 x 2 = 0.136 kN

Along length (ISMC 150 @ 16.4 kg/m) = 0.164 x 8 = 1.312 kN

Along width (ISMB 200 @ 25.4 kg/m) = 0.254 x 1.0 = 0.254 kN

Total weight W_s = 1.7 kN

Weight of grating, W_g = 50 kg/m^2

Total weight of grating W_g = 0.5 x 8 x 1.0

= 4.0 kN

Weight of handrails W_h = 25 kg/m

Total weight of handrails W_h = 4.0 kN

Total weight of walkway = $W_s + W_g + W_h$

= 1.7 + 4 + 4

= 9.7 kN

Live Load Calculation for walkway

Imposed load on walkway w_{IL} = 250 kg/m^2

Total imposed load W_{IL} = w_{IL} x L_s x B

= 607.5 kg

= 6.075 kN

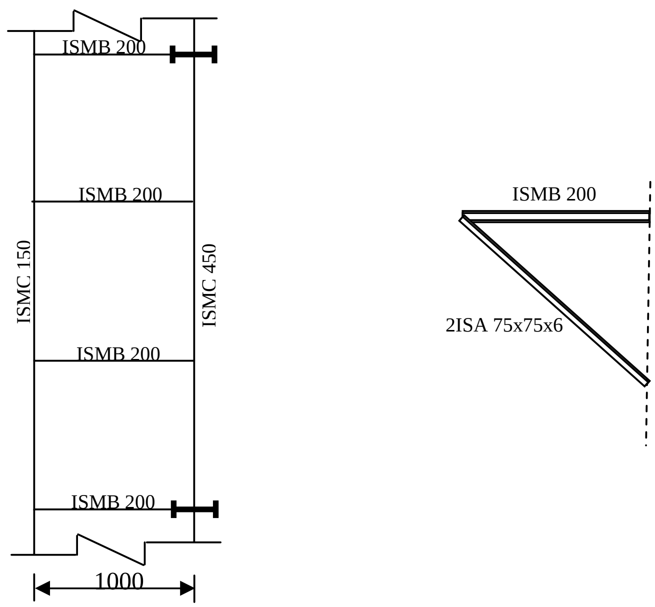


Fig 5.8 Details of Cantilevered Walkway

5.3.1.6 Load from Pressure Safety Valve (PSV)

Weight of grating = 50 kg/m^2

Weight of supporting members = 25 kg/m^2

Weight of handrail = 25 kg/m^2

Totl dead load (at end span) = $w_g + w_s + w_h$

= $(w_g + w_s) \times 4 \times 2.0 + w_h \times (2.0 + 4 \times 2)$

= $(0.5 + 0.25) \times 4 \times 2.0 + 0.25 \times (2.0 + 4 \times 2)$

= 6.0 + 2.5

= 8.5 kN

Total dead load (at end span) = $w_g + w_s + w_h$

= $(w_g + w_s) \times 8 \times 2.0 + w_h \times 8 \times 2$

= $(0.5 + 0.25) \times 8 \times 2.0 + 0.25 \times 8 \times 2$

= 12 + 4.0

= 16.0 kN

5.3.1.7 Staircase Load

a. Loads on Stair

Self weight of grating = 50 kg/m^2

Self Weight of supporting members = 100 kg/m^2

Live load = 500 kg/m^2

Total load = 650 kg/m^2

= 6.5 kN/m^2

b. Load on stringer beam

Max. vertical height	= 3500 mm
Assuming 185 mm riser	
Number of risers	= 3500 / 185
	= 19
Number of trades	= 19
Horizontal Span	= 230 x 19 + 1815 x 2
	= 8000 mm
UDL on stringer beam	= 6.5 x 0.9/2
	= 2.925 kN/m

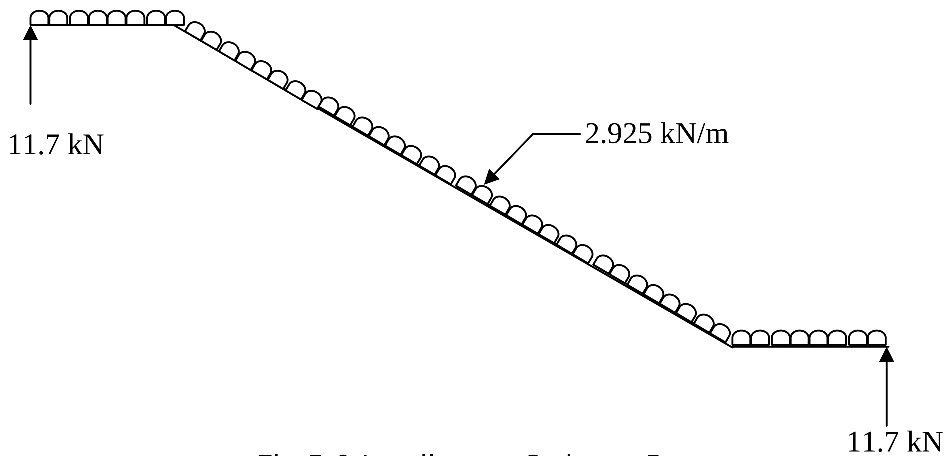


Fig 5.9 Loading on Stringer Beam

c. Forces in member of bracket

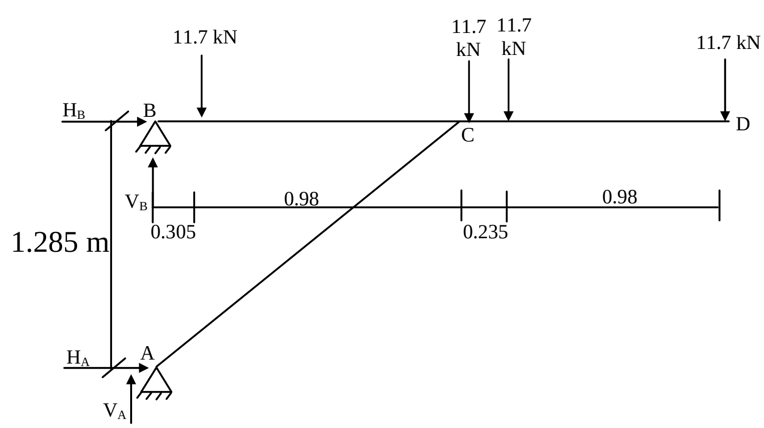


Fig 5.10 Loading on Bracket

$V_A + V_B = 11.7 \times 4 = 46.8$ kN

Taking moment @ B,

$$H_A \times 1.285 = 11.7 \times 0.25 + 11.7 \times 1.285 + 11.7 \times 1.52 + 11.7 \times 2.5$$

$$= 65 \text{ kN m}$$

$$\therefore H_A = 50.6 \text{ kN}$$

$$F_{AC} \cos 45 = H_A$$

$$\therefore F_{AC} = 71.56 \text{ kN}$$

$$V_A = F_{AC} \sin 45$$

$$= 50.60 \text{ kN}$$

Taking moment @ C,

$$F_{AC} \cos 45 = F_{BC}$$

$$\therefore F_{BC} = 50.60 \text{ kN}$$

Taking moment @ A,

$$H_B = F_{BC} = 50.60 \text{ kN}$$

Also,

$$V_A + V_B = 46.8 \text{ kN}$$

$$\therefore V_B = 46.8 – 50.6$$

$$= - 3.8 \text{ kN}$$

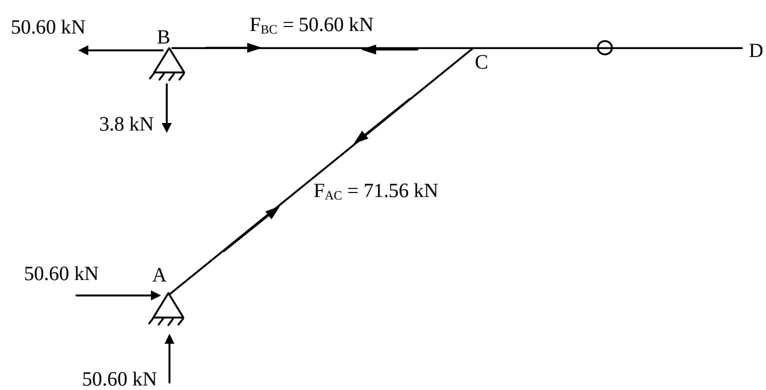


Fig 5.11 Forces in Members of Bracket

5.3.2 Piping Load

5.3.2.1 Pipe Empty Loads

1. Main Transverse Beam

Table 5.3 Pipe Empty Load on Transverse Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	105	107	109	112
Spacing of main beams (m)	8	8	8	8
Pipe Load (kN/m^2) UDL (w1) Width of udl (m)	1.25 10.0 8	1.25 10.0 8	1.25 10.0 6.6	1.25 10.0 8
Point Load P1 (kN) Location of Load (m)			16.56 0.91	
1Total Load on Beam (kN)	80	80	69.36	80

2. Longitudinal Beam

Longitudinal beam shall be designed for 25% of total load on main transverse beams. Total load shall be assumed as two equal concentrated loads acting at 1/3rd span.

Table 5.4 Pipe Empty Load on Longitudinal Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	104	106	108	110
Spacing of long beams (m)	8	8	8	8
Total load on main beam (kN)	80.00	80.00	69.36	80.00
Point load on long. beam	10.00	10.00	8.67	10.00
Dist of point load (L/3)	2.667	2.667	2.667	2.667

3. Intermediate Beam at tier level

Intermediate beam shall be designed for 25% of total load on main transverse beams.

Table 5.5 Pipe Empty Load on Intermediate Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	104	106	108	110
Load on main Beam (kN/m)	10	10	8	10
Load on secondary beam (kN/m)	2.50	2.50	2.50	2.50
Width of UDL (m)	8	8	6.6	8

5.3.2.2 Pipe Operating Loads

1. Main Transverse Beam

Table 5.6 Pipe Operating Load on Transverse Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	105	107	109	112
Spacing of main beams (m)	8	8	8	8
Pipe Load (kN/m^2) UDL (w1) Width of udl (m)	1.75 14.0 8	1.75 14.0 8	1.25 10.0 6.6	1.75 14.0 8
Point Load P1 (kN) Location of Load (m)			19.52 0.91	
Total Load on Beam (kN)	112	112	85.52	112

2. Longitudinal Beam

Longitudinal beam shall be designed for 25% of total load on main transverse beams.

Table 5.7 Pipe Operating Load on Longitudinal Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 – 7
EL	104	106	108	110
Spacing of long beams (m)	8	8	8	8

Total load on main beam (kN)	112	112	85.52	112
Point load on long. beam	14.00	14.00	10.00	14.00
Dist of point load (L/3)	2.667	2.667	2.667	2.667

3. Intermediate Beam at tier level

Intermediate beam shall be designed for 25% of total load on main transverse beams.

Table 5.8 Pipe Operating Load on Intermediate Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	104	106	108	110
Load on main Beam (kN/m)	14.00	14.00	10.00	14.00
Load on secondary beam (kN/m)	3.50	3.50	2.50	3.50
Width of UDL (m)	8	8	6.6	8

5.3.2.3 Pipe Test Loads

a. Main Transverse Beam

Table 5.9 Pipe Test Load On Transverse Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	105	107	109	112
Spacing of main beams (m)	8	8	8	8
Pipe Load (kN/m^2) UDL (w1) Width of udl (m)	2.00 16.0 8	2.00 16.0 8	2.00 14.0 6.6	2.00 16.0 8
Point Load P1 (kN) Location of Load (m)			16.56 0.91	
Total Load on Beam (kN)	128	128	108.96	128

b. Longitudinal Beam

Longitudinal beam shall be designed for 25% of total load on main transverse beams. Total load shall be assumed as two equal concentrated loads acting at 1/3rd span.

Table 5.10 Pipe Test Load On Longitudinal Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 – 7
EL	104	106	108	110
Spacing of long beams (m)	8	8	8	8
Total load on main beam (kN)	128	128	108.96	128
Point load on long. beam	16.00	16.00	13.62	16.00
Dist of point load (L/3)	2.667	2.667	2.667	2.667

c. Intermediate Beam at tier level

Intermediate beam shall be designed for 25% of total load on main transverse beams.

Table 5.11 Pipe Test Load on Intermediate Beam

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	104	106	108	110
Load on main Beam (kN/m)	16	16	14	16
Load on secondary beam (kN/m)	4	4	3.5	4
Width of UDL (m)	8	8	6.6	8

5.3.2.4 Friction And Anchor Force

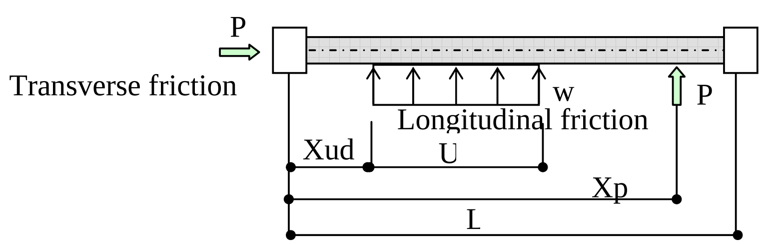


Fig 5.12 Friction Force

a. Friction force in longitudinal direction

Table 5.12 Friction Force On Longitudinal Direction

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	105	107	109	112
Pipe Operating Load (kN/m)	14.00	14.00	10.00	14.00
Factor for Friction force	0.10	0.10	0.10	0.10

Thermal friction force (kN/m)	1.40	1.40	1.00	1.40
Width of UDL (m)	8.00	8.00	6.60	8.00
Pipe operating Load (P1) (kN)			19.52	
Factor for friction force			0.30	
Thermal friction force (kN)			5.86	
Location of Load (Xp1) (m)			0.91	

b. Friction force in Transverse direction

Table 5.13 Friction Force on Transverse Direction

Tier	1	2	3	4
Grids	1 - 7	1 - 7	1 - 7	1 - 7
EL	105	107	109	112
Total Load on main beam (kN)	112.0	112.0	85.52	112.0
Factor for friction force (kN)	0.10	0.10	0.10	0.10
Point load at tier level (kN)	11.2	11.2	8.552	11.2

c. Anchor force is taken from piping input data as given in Appendix A

5.3.3 Wind Load Calculation as per IS 875 (Part III) – 1987

Location = Madras

Basic Wind Speed, Vb = 50 m/s *(Cl: 5.2)*

Risk Coefficient k_1 = 1 *(Cl: 5.3.1, Table 1)*

Topography factor = 1 *(Cl: 5.3.3)*

Terrain Category = Category 3 *(Cl: 5.3.2.1)*

Class of structure = Class B *(Cl: 5.3.2.2)*

K_2 Factor

Height (m)	K_2	V_z(m/s)	P_z (N/m^2)	P_z (kN/m^2)
10.00	0.880	44.00	1162	1.162
13.50	0.922	46.10	1275	1.275

Where,

(Design Wind Speed - $V_z = k_1 \times k_2 \times k_3 V_b$)

(Corresponding design wind pressure : $P_z = 0.6 (V_z)^2$

a. Determination of wind load coefficient, Cf

Effective area (A_{eff}) :-

Table 5.14 Effective Area Calculation

Member	Breadth (m)	Length (m)	Nos.	Area (m^2)
(1)	(2)	(3)	(4)	(5) = (2) x (3) x (4)
Column – C1	0.620	5.00	2	6.20
Column – C2	0.600	2.00	2	2.40
Column – C3	0.600	2.00	2	2.40
Column – C4	0.600	3.00	2	3.60
Column – C5	0.600	1.50	2	1.80
Beam – TB1	0.550	7.50	1	4.10
Beam – TB2	0.550	7.50	1	4.10
Beam – TB3	0.550	7.50	1	4.10
Beam – TB4	0.400	7.50	1	3.00
Beam – TB5	0.450	7.50	1	3.40
		Total Effective Area		35.08

Total Area

A_{total} = (W+C) x H
= (8+0.62) x 13.5
= 116.37 m^2

Therefore,
Solidity Ratio, ϕ
= A_{eff}/A_{total}
ϕ = 0.301

Force Coefficient (for single frame)

Cf = 1.7 (Cl: 6.3.3.3, Table 28 , IS- 875(part III)-1987)

Frame Spacing
S = 8.000 m

Least overall Frame Dimension
D_{min} = 8.000 m

Frame Spacing Ratio, S.R.
S.R. = S/D_{min}
= 1

Number of Frames
n = 7

a. Wind load Calculation at different joints (Longitudinal direction, W_x)

On each grid L&M

Effective solidity ratio

β = ϕ [Cl : 6.3.3.4(b)]

Shielding factor

η = 0.799 [Cl : 6.3.3.3, Table 29]

Total force coeff, $C_{f,total}$ = $C_f \times [1+(n-1) \times \eta]$

For succeeding frames, $C_{f,s}$ = $C_f \times \eta$ = 1.36

Table 5.15 Wind Force in Longitudinal Direction

EL	Joint No.	Memb	Force	Wind Pre.	Effective area			Total wind force	
			C_f, total	P_z (kN/m^2)	Length (m)	Width (m)	Area (m^2)	F (kN)	F, total (kN)
105.0	114, 86	Col	9.84	1.162	2.35	0.62	1.46	16.76	46.82
		Col	9.84	1.162	1.00	0.60	0.60	6.86	
		Beam	9.84	1.162	3.69	0.55	2.03	23.20	
107.0	121, 93	Col	9.84	1.162	2.00	0.60	1.20	13.72	37.29
		Beam	9.84	1.162	3.75	0.55	2.06	23.57	
109.0	128, 100	Col	9.84	1.162	2.50	0.60	1.50	17.15	40.72
		Beam	9.84	1.162	3.78	0.55	2.06	23.57	
112.0	135, 107	Col	9.84	1.275	2.25	0.60	1.35	16.94	35.76
		Beam	9.84	1.275	3.75	0.40	1.50	18.82	
113.5	36, 78	Col	9.84	1.275	0.75	0.60	0.45	5.65	26.82
		Beam	9.84	1.275	3.75	0.45	1.68	21.17	
				Total base shear in longitudinal direction					374.82

c. Wind Load Calculation at Different Joints : (Transverse direction, Wz)

On each grid L & M

Wind Force at each tier level (N)

$F = K.P_z.S$

where,

P_z = Design wind pressure (N/m^2)

S= Spacing of portals (m)

k = Force coefficient for pipe rack (including wind load factor for pipe)

Width of Piperack	k
Upto 4 m	1.25
Above 4m upto 6m	1.50
Above 6m upto 10m	2.00
Above 10m upto 12m	2.50

Width of Piperack = 8 m
k = 2.00

Table 5.16 Wind Force in Transverse Direction

EL	Joint No.	Force coeff.	Wind Pre.	Spacing	Wind Force
		$C_{f,\ total}$	P_z ($kN.m^2$)	(m)	F (kN)
105.00	31	2.00	1.16	8.00	18.59
	34	2.00	1.16	8.00	18.59
	38	2.00	1.16	8.00	18.59
	41	2.00	1.16	8.00	18.59
	44	2.00	1.16	8.00	18.59
	47	2.00	1.16	8.00	18.59
	50	2.00	1.16	8.00	18.59
107.00	63	2.00	1.16	8.00	18.59
	72	2.00	1.16	8.00	18.59
	76	2.00	1.16	8.00	18.59
	80	2.00	1.16	8.00	18.59
	84	2.00	1.16	8.00	18.59
	88	2.00	1.16	8.00	18.59
	92	2.00	1.16	8.00	18.59
109.00	111	2.00	1.16	8.00	18.59
	114	2.00	1.16	8.00	18.59
	121	2.00	1.16	8.00	18.59
	124	2.00	1.16	8.00	18.59
	127	2.00	1.16	8.00	18.59
	130	2.00	1.16	8.00	18.59
112.00	149	2.00	1.28	8.00	20.40
	152	2.00	1.28	8.00	20.40
	156	2.00	1.28	8.00	20.40
	162	2.00	1.28	8.00	20.40
	165	2.00	1.28	8.00	20.40
	168	2.00	1.28	8.00	20.40
113.5	171	2.00	1.28	8.00	20.40
	173	2.00	1.28	8.00	20.40
	178	2.00	1.28	8.00	20.40
	180	2.00	1.28	8.00	20.40
	182	2.00	1.28	8.00	20.40
	184	2.00	1.28	8.00	20.40
	186	2.00	1.28	8.00	20.40
		Total base shear in transverse direction			636.90

5.3.4 Calculation for Seismic force as per IS 1893-2002

5.3.4.1 Basic Parameters

Town (Location)		=	Chennai
Zone Factor, Z	*(Cl: 6.4.2,Table 2)*	=	0.16
Importance Factor, *I*	(Cl: 6.4.2,Table 6)	=	1
Response reduction factor(R)	*(Cl: 6.4.2,Table 7)*		
X Direction		=	4
Y Direction		=	5
Height of Structure		=	13.5 m
Length of Structure (x direction)		=	56 m
Length of Structure (z direction)		=	8 m

Time period :- *(Cl: 7.6, Fundamental Natural Period)*

Type of Building as Steel building without brick infill

(Ta)x	*(Cl: 7.6)*	=	0.599 Sec
(Ta)z	*(Cl: 7.6)*	=	0.599 Sec
Soil Type		=	Medium Soil
(Sa/g)x	*(Cl: 6.4.5, Fig 2)*	=	2.27
(Sa/g)z	*(Cl: 6.4.5, Fig 2)*	=	2.27

Design seismic coefficient :- *(Cl: 6.4.2)*

$(A_h)x$ = 0.0454

$(Ah)z$ = 0.0363

Design Seismic Base Shear :- *(Cl:7.5.3)*

$V_{B\ (x\ direction)}$ = 338.192 kN

$V_{B\ (z\ direction)}$ = 270.553 kN

5.3.4.2 Lump Mass from STAAD output

EL 104 to 105

Grid	1	2	3	4	5	6	7
Lump Mass	93.49	102.5	102.4	108.4	108.5	108.5	93.53
Grid	1	2	3	4	5	6	7
Lump Mass	110.0	105.7	102.4	108.4	108.5	108.5	93.57

EL 106 to 107

Grid	1	2	3	4	5	6	7
Lump Mass	88.36	97.57	98.05	104.3	104.3	104.4	88.82
Grid	1	2	3	4	5	6	7
Lump Mass	88.36	97.57	98.05	104.3	104.3	104.4	88.82

EL 108 to 109

Grid	1	2	3	4	5	6	7
Lump Mass	119.2	86.7	86.64	92.41	92.45	92.50	77.47
Grid	1	2	3	4	5	6	7
Lump Mass	72.79	82.04	81.99	87.75	87.8	87.85	101.8

EL 110 to 112

Grid	1	2	3	4	5	6	7
Lump Mass	91.63	101.5	101.5	107.9	107.9	107.9	91.66
Grid	1	2	3	4	5	6	7
Lump Mass	108.1	104.7	101.4	107.8	107.8	107.9	91.59

EL 113.5

Grid	1	2	3	4	5	6	7
Lump Mass	132.1	143.7	142.7	184.8	196.4	171.9	118.3
Grid	1	2	3	4	5	6	7
Lump Mass	102.8	98.76	142.7	155.1	127.3	127.3	82.84

Total Lump mass = 7443 kN

5.3.4.3 Distribution Of Design Force In Longitudinal Direction

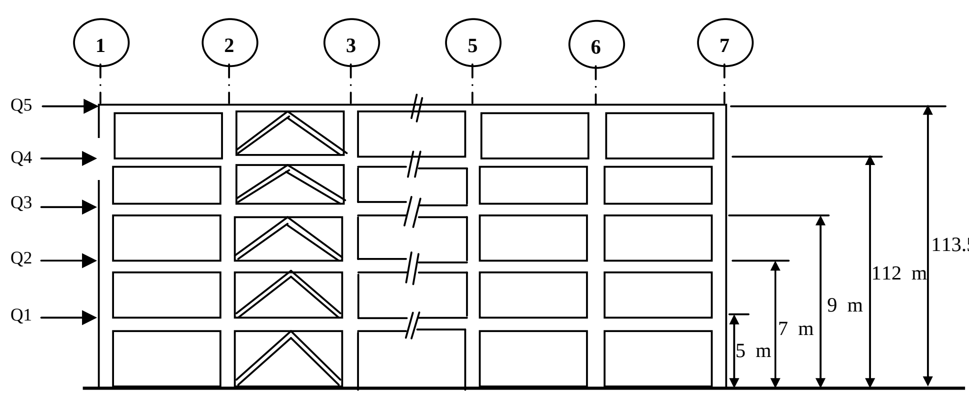


Fig 5.13 Distribution of Design Seismic Force in Longitudinal Dir

Table 5.17 Distribution of Design Seismic Force in Longitudinal Dir.

EL –Grid in X dir		Height	Lump Mass (Wi)		Total	Wi x hi^2	Qi
EL	Grid	h (m)	Grid L	Grid M	Wi (kN)		(kN)
105.0	1	5	93.49	110.0	203.5	5089	1.80
	2	5	102.5	105.7	208.2	5207	1.85
	3	5	102.4	102.4	204.9	5125	1.82
	4	5	108.4	108.4	216.9	5423	1.92
	5	5	108.4	108.5	217.0	5428	1.92
	6	5	108.5	108.5	217.1	5428	1.92
	7	5	93.53	93.53	187.0	4677	1.66
107.0	1	7	88.36	88.36	176.7	8659	3.07
	2	7	97.57	97.57	195.1	9562	3.39
	3	7	98.05	98.05	196.1	9609	3.41
	4	7	104.3	104.3	208.7	10227	3.62
	5	7	104.4	104.3	208.6	10224	3.62
	6	7	104.4	104.4	208.9	10239	3.63
	7	7	88.82	88.82	177.6	8704	3.09
109.0	1	9	119.2	72.79	192.0	15556	5.51
	2	9	86.70	82.04	168.7	13668	4.84
	3	9	86.64	81.99	168.6	13659	4.84
	4	9	92.41	87.75	180.1	14593	5.17
	5	9	92.45	87.80	180.2	14600	5.17
	6	9	92.50	87.85	180.3	14608	5.18
	7	9	77.47	101.8	179.2	14522	5.15
112.0	1	12	91.63	108.1	199.7	28764	10.19
	2	12	101.5	104.7	206.3	29716	10.53
	3	12	101.5	101.4	202.9	29223	10.36
	4	12	107.9	107.8	215.7	31062	11.01
	5	12	107.9	107.8	215.8	31077	11.02
	6	12	107.9	107.9	215.9	31091	11.02
	7	12	91.66	91.59	183.2	26388	9.35
113.5	1	13.5	132.1	102.8	234.9	42825	15.18
	2	13.5	143.7	98.76	242.4	44188	15.66
	3	13.5	142.7	142.7	285.5	52043	18.45
	4	13.5	164.8	155.1	339.9	61960	21.96
	5	13.5	196.4	127.3	323.7	59007	20.91
	6	13.5	171.9	127.3	299.2	54542	19.33
	7	13.5	118.3	82.84	201.1	36661	12.99
				Total	Wihi^2	763353	

5.3.4.4 Distribution of design force in transverse direction

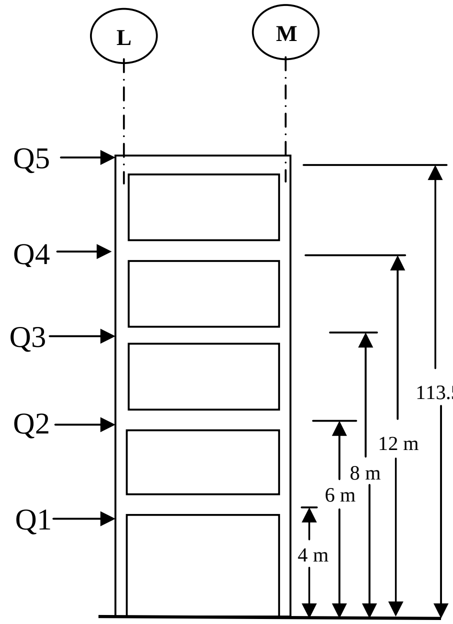


Fig 5.14 Distribution of Design Seismic Force in Transverse Dir

Table 5.18 Distribution of Design Seismic Force in Transverse Dir.

EL –Grid in Z- Dir		Height	Lump mass per column in kN							Total	Wihi²	Qi
EL	Grid	(m)	1	2	3	4	5	6	7	W (kN)		(kN)
105	L	4	93.49	102.54	102.49	108.46	108.51	108.56	93.53	717.58	11481	5.99
	M	4	110.08	105.75	102.49	108.46	108.51	108.56	93.53	737.38	11798	6.16
												0.00
107	L	6	88.36	97.57	98.05	104.35	104.33	104.48	88.82	685.96	24695	12.89
	M	6	88.36	97.57	98.05	104.36	104.33	104.48	88.82	685.97	24695	12.89
109	L	8	119.26	86.7	86.64	92.41	92.45	92.5	77.47	647.43	41436	21.63
	M	8	72.79	82.04	81.99	87.75	87.8	87.85	101.82	602.04	38531	20.11
112	L	10	91.63	101.57	101.52	107.9	107.94	107.99	91.66	710.21	71021	37.08
	M	10	108.12	104.79	101.42	107.81	107.87	107.92	91.59	729.52	72952	38.08
113.5	L	13.5	132.11	143.7	142.78	184.82	196.45	171.95	118.32	1090.13	198676	103.72
	M	13.5	102.87	98.76	142.78	155.15	127.32	127.32	82.84	837.04	152551	79.64
										SWihi²	**647835**	

From load calculation for wind load and seismic load, base shear for wind is larger then base shear for seismic load obtain in both direction from this we can conclude that wind load can be governing load.

5.4 LOAD INPUT IN STAAD Pro.

5.4.1 Dead Load

1. Selfweight of members is generated by STAAD Pro. As per the specified densities of material

2. Fireproofing is applied as uniformly distributed load on each member

3 Dead Load of walkway and cable tray on transverse beam at 113.5 m level is applied as follows:

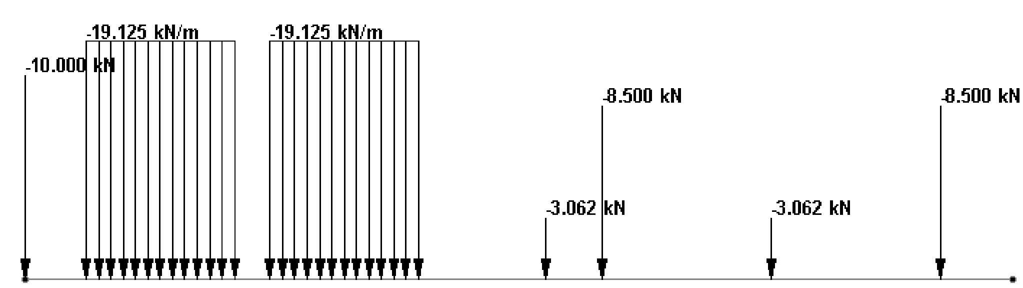


Fig 5.15 Dead Load of Walkway and Cable Tray

4. Dead Load from secondary beams (portal), cantilevered walkway and staircase is transferred as point load on longitudinal beam as shown below figure.5.16 and figure 5.17 respectively.

Fig 5.16 Dead Load Reaction due to Portal & Cantilevered Walkway

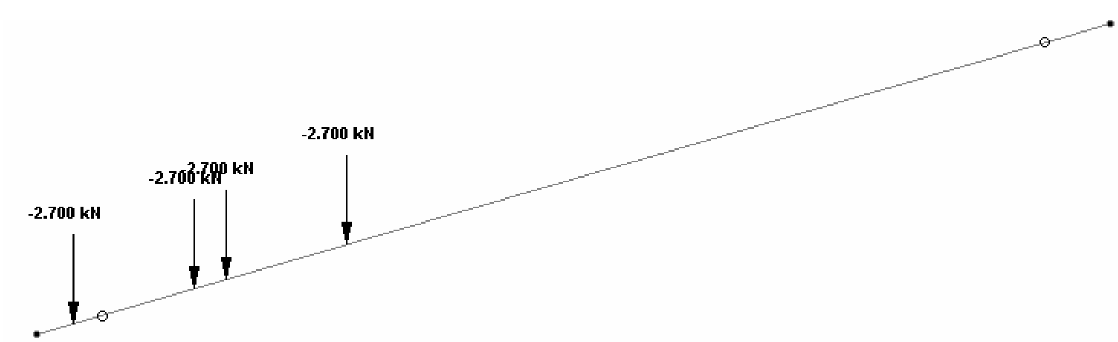


Fig 5.17 Dead Load Reaction due to Stair Case

5.4.2 Live Load

1. Live load of walkway and cable tray on transverse beam at 113.5 m level is applied as follows:

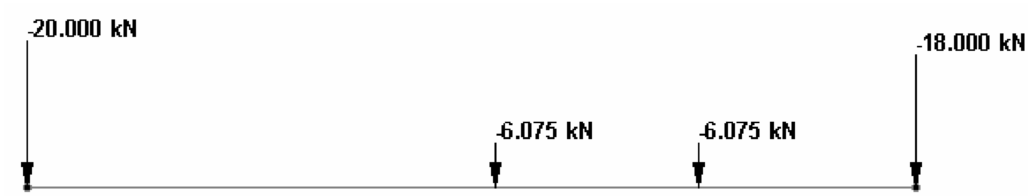


Fig 5.18 Live Load of Walkway and Cable Tray

2. Live Load from secondary beams (portal), cantilevered walkway and staircase is transferred as point load on longitudinal beam as shown below figure.5.19 and figure 5.20 respectively.

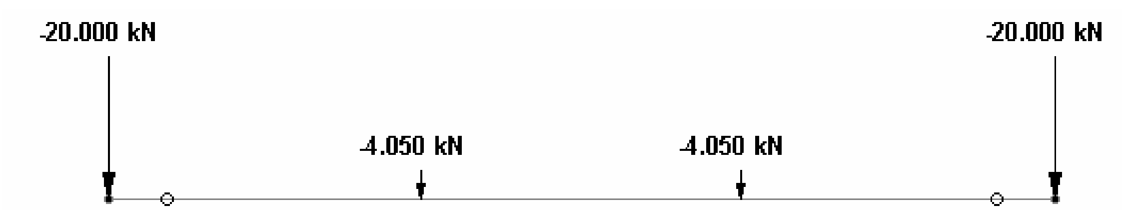


Fig 5.19 Live Load Reaction due to Portal & Cantilevered Walkway

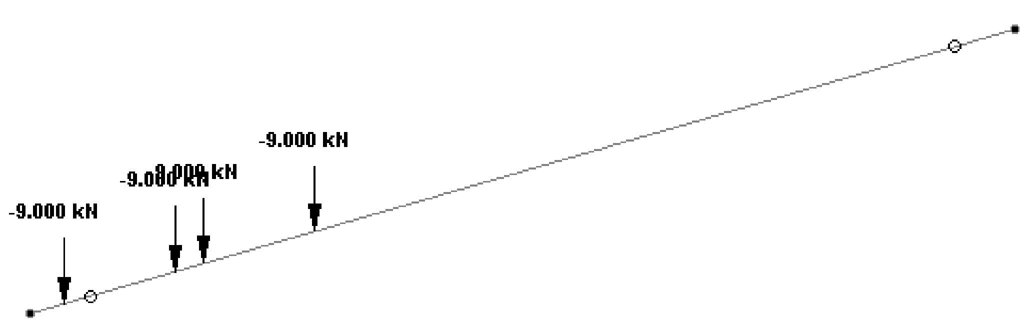


Fig 5.20 Live Load Reaction due to Stair Case

5.4.3 Piping Load

Piping load for different condition as empty, test and operating is applied in form of uniformly distributed load (UDL) on transverse beam with respective load values. Standard loading diagram for piping load on transverse frame is as shown in figure 5.21

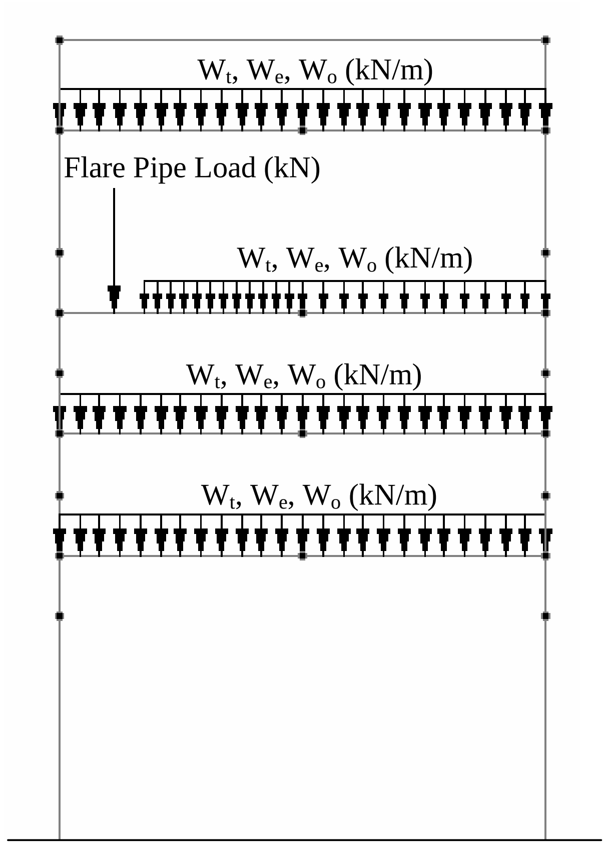


Fig 5.21 Piping Load

5.4.4 Friction Force

Longitudinal friction force is consider as uniformly distributed load over the entire span of beam and transverse friction force is consider as a concentrated load at each tier level.

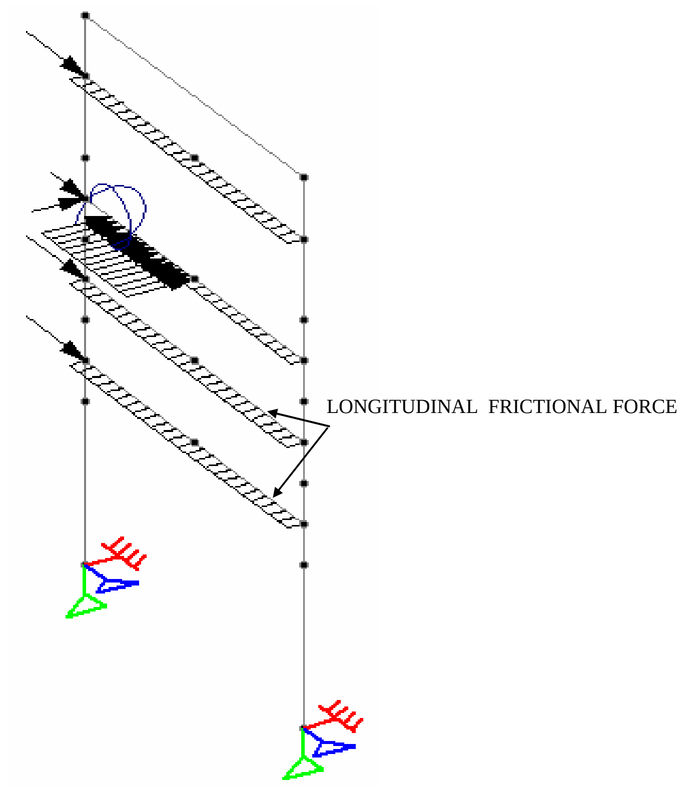


Fig 5.22 Friction Force

5.4.5 Anchor Force

Anchor force is applied as concentrated load and concentrated moment in X and Z direction in bay number 5th as shown in figure (Refer Appendix A)

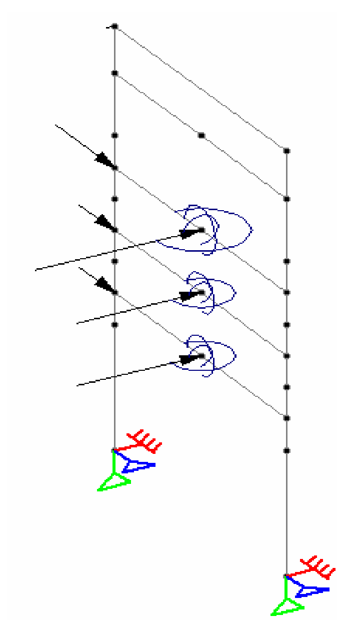


Fig 5.23 Anchor Force

5.4.6 Wind Load

a. Wind load in x- direction is applied as shown in figure 5.24

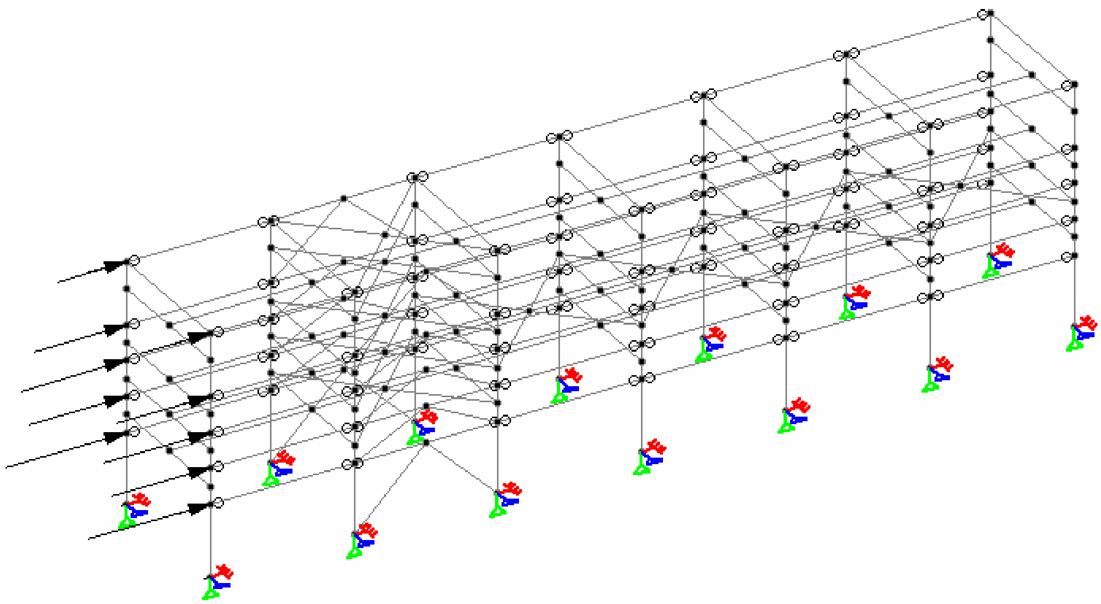


Fig 5.24 Wind Load in X - Direction

b. Wind load in z- direction is applied as shown in figure 5.25

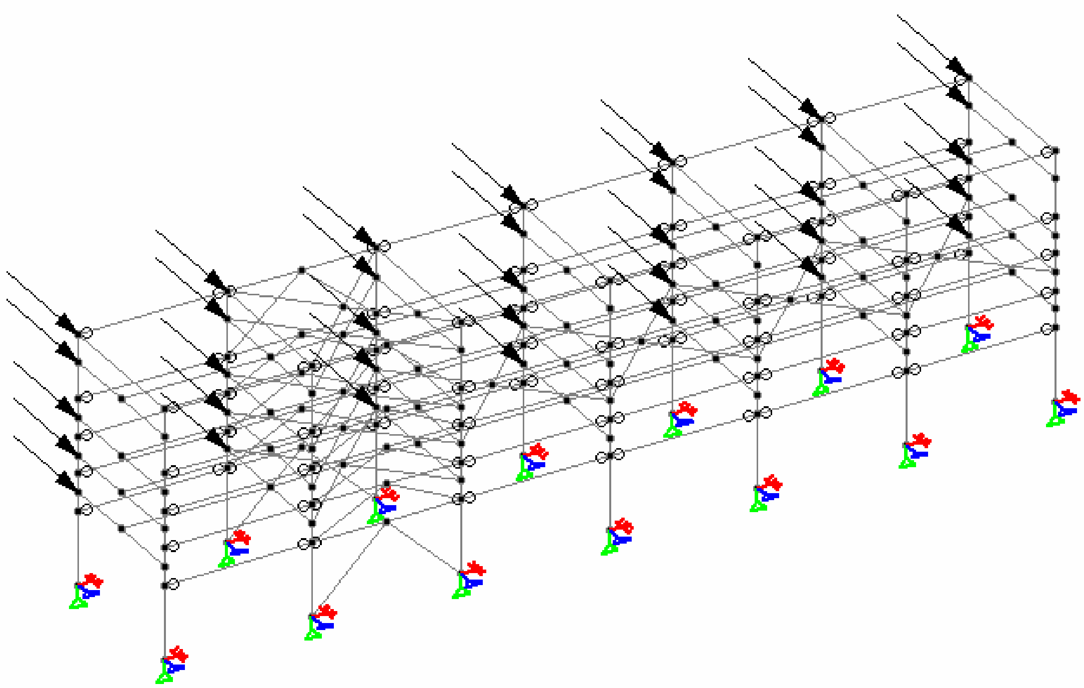


Fig 5.25 Wind Load in Z - Direction

5.4.7 Seismic Force

a. Seismic force in x & z direction is applied as shown in figure 5.26 & 5.27

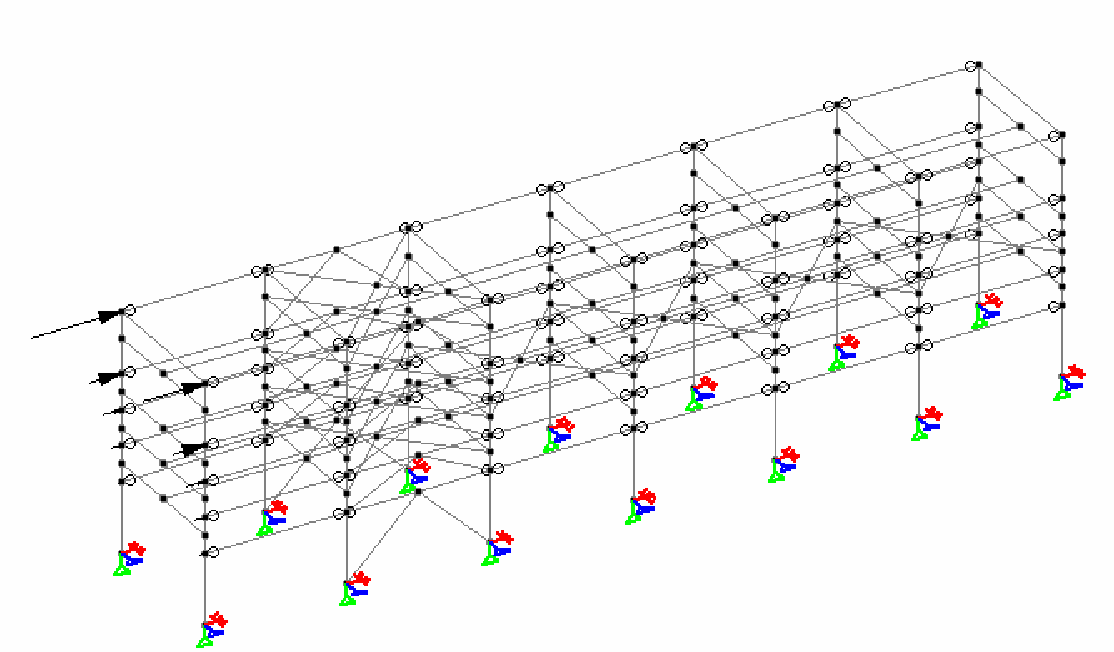


Fig 5.26 Seismic Force in X - Direction

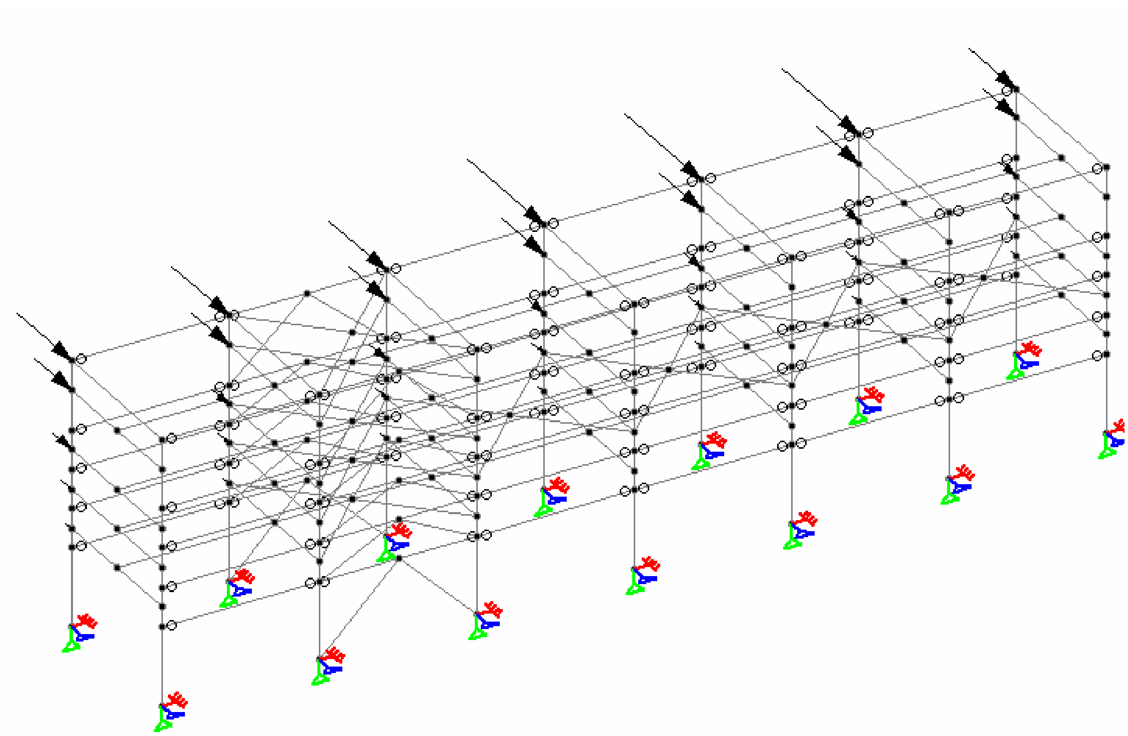


Fig 5.27 Seismic Force in Z - Direction

5.5 ANALYSIS AND DESIGN SUMMARY

5.5.1 Transverse Frame

a. Governing load case for transverse beams

- Dead Load + Live Load + 90 % Pipe Operating Load – Friction Force – Anchor Force – Wind Load Z- dir

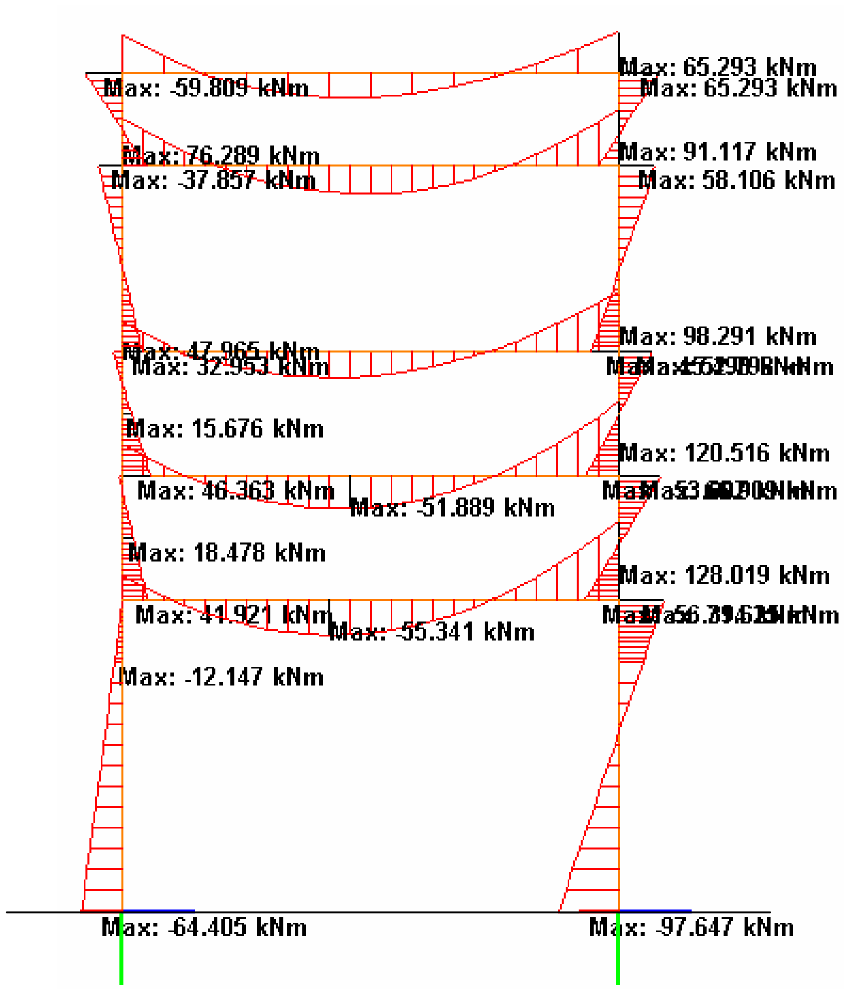


Fig 5.28 B.M. Diagram for Transverse Frame
For Long Term Case

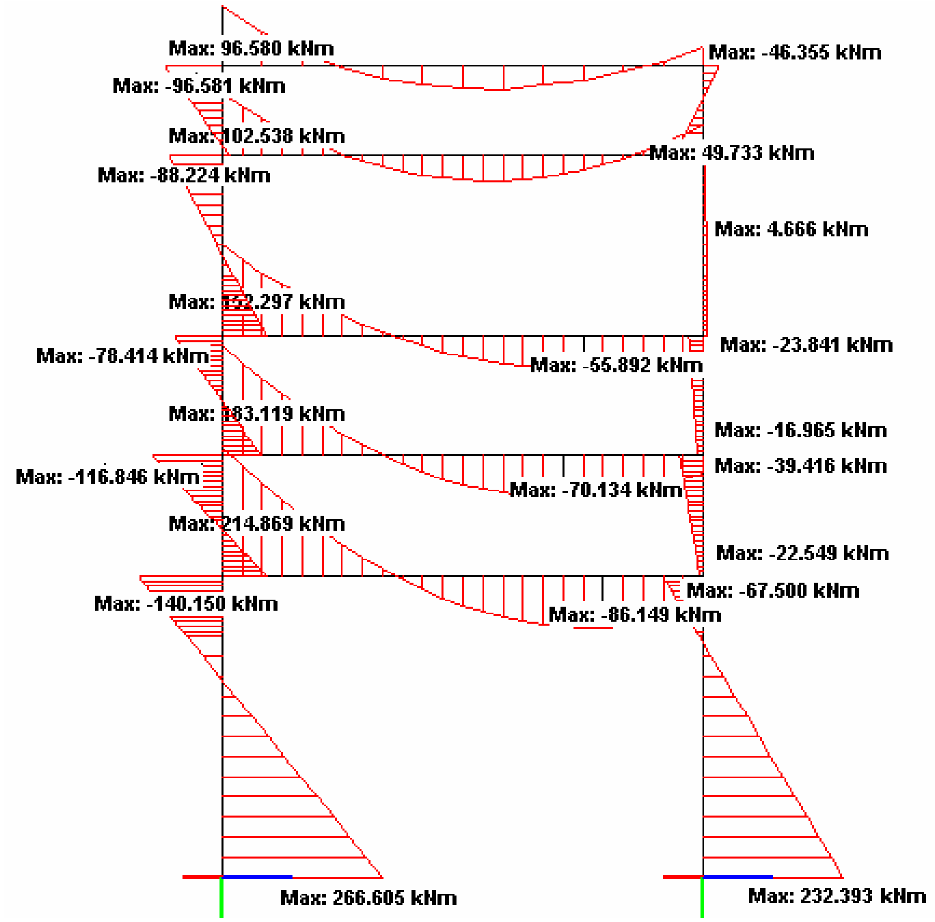


Fig 5.29 B.M. Diagram for Transverse Frame
For Short Term Case

b. Section displacement

Table 5.19 Section Displacement for Transverse Beams

Beam	Max Disp (mm)	Location (m)	Load case
79	1.399	1.333	112
99	1.064	1.333	112
119	0.927	1.333	112
139	1.042	1.000	112
159	4.376	4.667	112
272	1.739	2.000	112
279	1.384	2.000	112
286	1.118	2.000	112

Actual deflection = 4.367 mm

Length of transverse beam = 8 m

Permissible Deflection (IS 800) = L/325

= 24.61 mm > Actual defl.....Hence ok

5.5.2 Longitudinal Frame

a. Governing load case for longitudinal beams

- Dead Load + Live Load + Pipe Operating Load + Friction Force + Anchor Force + Wind Load X- dir

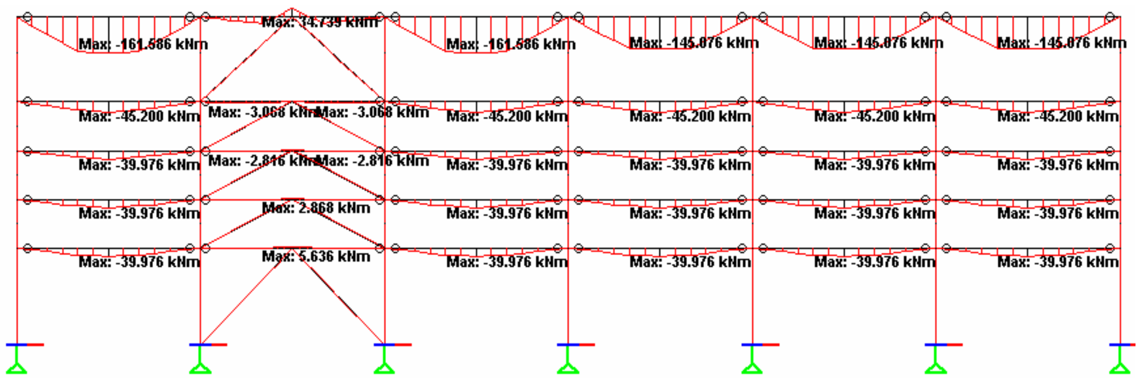


Fig 5.30 B.M. Diagram for Longitudinal Frame

b. Section displacement

Table 5.20 Section Displacement for Longitudinal Beams

Beam	Max Disp (mm)	Location (m)	Load case	Beam	Max Disp (mm)	Location (m)	Load case
8	13.271	4.00	103	39	13.271	4.00	103
9	0.0761	1.33	103	47	14.850	4.00	103
10	13.271	4.00	103	48	0.244	2.00	103
11	13.271	4.00	103	64	15.831	4.00	103
12	13.271	4.00	103	65	15.830	4.00	103
13	13.270	4.00	103	227	0.076	2.67	103
21	13.271	4.00	103	228	0.192	1.67	103
22	0.192	2.33	103	229	0.212	2.33	103
23	13.271	4.00	103	230	0.243	2.00	103
24	13.270	4.00	103	231	0.544	2.00	103
25	13.270	4.00	103	49	14.850	4.00	103
26	13.27	4.00	103	50	14.85	1.33	103
34	13.271	4.00	103	51	14.850	4.00	103
35	0.211	1.67	103	52	14.850	4.00	103
36	13.270	4.00	103	60	17.640	4.00	103
37	13.271	4.00	103	61	0.544	2.00	103
38	13.270	4.00	103	62	15.831	4.00	103

Actual deflection = 17.64 mm

Length of transverse beam = 8 m

Permissible Deflection (IS 800) = L/325

= 24.61 mm > Actual defl. ......Hence ok

5.5.4 Design Summary

Table 5.21 Design Summary

Sr. No	Member	Section Property	Stress Ratio		Remark
			Long Term	Short Term	
1	Column (upto EL 110.0)	ISMB 500 + 250 x 12 mm Thick plate	0.522	1.01	Ok
2	Column (Rest)	ISMB 500	0.802	0.986	Ok
3	Transverse Beams				
	At EL 105.00	ISMB 450	0.845	0.952	Ok
	At EL 107.00	ISMB 500	0.774	1.14	Ok
	At EL 109.00	ISMB 500	0.953	1.05	Ok
	At EL 113.50	ISMB 400	0.816	1.11	Ok
4	Longitudinal Beams				
	At EL 104.00	ISMB 300	0.772	0.987	Ok
	At EL 106.00	ISMB 300	0.750	0.850	Ok
	At EL 108.00	ISMB 300	0.780	0.890	Ok
	At EL 110.00	ISMB 300	0.857	0.985	Ok
	At EL 113.50	ISMB 450	0.956	1.080	Ok
5	Portal	ISMB 300	0.695	0.695	Ok
6	Vertical Bracing				
	At EL 105.00	Star 110 x 110 x 12	0.735	1.18	Ok
	Rest	Star 100 x 100 x 10	0.622	0.92	Ok
7	Plan Bracing	2ISA 90 x 90 x 8	0.419	0.438	Ok
8	Strut	2ISA 75 x 75 x 8	0.185	1.28	Ok
		2ISA 90 x 90 x 8	0.332	1.02	Ok

5.5.5 Manual Checks For Design [7]

5.5.5.1 Design Of Column

1.Loads

Axial force (P)	=	782.89	kN
Bending moment @ major axis (Mx)	=	309.4	kN-m

2. Effective Length Of Column

Eff. Length @ x-axis (leffx)	=	3.70	m
Eff. Length @ y-axis (leffy)	=	4.70	m

3. Section Properties

Section details	=	ISMB500 + 250 X 12 mm Thk Plate.	
Area of section (Ax)	=	17074.00	mm^2
Moment of inertia @ major axis (Ixx)	=	8.45E+08	mm^4
Moment of inertia @ minor axis (Iyy)	=	4.49E+07	mm^4
Moduli of section @ major axis (Zxx)	=	3.23E+06	mm^3
Moduli of section @ minor axis (Zyy)	=	3.60E+05	mm^3
Radius of gyration @ major axis (rxx)	=	222.53	mm
Radius of gyration @ minor axis (ryy)	=	51.31	mm
Weight of section	=	134.00	Kg / m
Thickness of flange (T)	=	24.38	mm
Thickness of web (t)	=	10.20	mm
Overall depth (D)	=	524.00	mm
Clear depth of web (d1)	=	465.60	mm
Modulus of elasticity of steel	=	200000	MPa
Yield stress of steel	=	250	MPa

4. Calculation Of Axial Stresses

Actual compressive stress (σ_{ac},cal) = P / Ax

= 778120 / 17074

= 45.87 MPa

Actual bending stress @ major axis (σ_{bcx},cal) = Mx / Zxx

= 309.4E+06/ 3.23E+06

= 95.80 MPa

5. Calculation Of Permissible Stresses

Slenderness ratio in minor direction (λ_y) = l_Y / r_{yy}

= 3700 / 51.31

= 72.54

∴ From table 5.1 of IS 800 –1984

For fy = 250 Mpa

Permissible compressive stress (σ_{ac}) = 109.32 MPa > σ_{ac},cal

Hence Ok

Permissible Bending Stress :-

$T/t = 24.38/10.2 = 3.39 < 2.0$;

$d_1/t = 465.6/10.2 = 45.64 < 85$;

∴ From table 6.1B of IS 800 –1984

For $D/T = 524/24.38 = 21.5$; & $l/r_y = 3700/51.31 = 72.54$;

Permissible bending stress ((σ_{bcx}) = 136.32 MPa > $\sigma_{bcx,cal}$

Hence Ok

6. Check For Combine Stresses

∴ Using Cl.: 7.1.1 of IS 800 – 1984

$$\frac{\sigma_{ac,cal}}{\sigma_{ac}} + \frac{\sigma_{bcx,cal} \times C_{mx}}{\left\{1 - \frac{\sigma_{ac,cal}}{0.6 \times f_{ccx}}\right\} \times \sigma_{bcx}} + \frac{\sigma_{bcy,cal} \times C_{my}}{\left\{1 - \frac{\sigma_{ac,cal}}{0.6 \times f_{ccy}}\right\} \times \sigma_{bcy}} < 1.33$$

where $C_{mx} = 0.85$

$C_{my} = 0.85$

$f_{cc} = \Pi^2 E / \lambda^2$

$= 375.12$ MPa

$$\frac{45.87}{109.32} + \frac{95.80 \times 0.85}{\left[1 - \frac{45.87}{0.6 \times 375.12}\right] \times 136.32} = 1.0087 < 1.33$$

Hence Ok

Design ratio from staad is 1.01 and manual is ~1.01 hence staad design is verified

5.5.5.2 Design of Beam

1. Loads

Axial force (P)	=	50.17	kN
Bending moment @ major axis (Mx)	=	101.57	kN-m

2. Effective Length Of Beam

Eff. Length @ x-axis (leffx)	=	8.00	m
Eff. Length @ y-axis (leffy)	=	4.00	m

3. Section Properties

Section details	=	ISMB350	
Area of section (Ax)	=	6671.00	mm^2
Moment of inertia @ major axis (Ixx)	=	5.38E+06	mm^4
Moment of inertia @ minor axis (Iyy)	=	1.37E+07	mm^4
Moduli of section @ major axis (Zxx)	=	7.79E+05	mm^3
Moduli of section @ minor axis (Zyy)	=	7.68E+04	mm^3
Radius of gyration @ major axis (rxx)	=	142.94	mm
Radius of gyration @ minor axis (ryy)	=	28.39	mm
Weight of section	=	52.40	Kg / m
Thickness of flange (T)	=	14.20	mm
Thickness of web (t)	=	8.10	mm
Overall depth (D)	=	350.00	mm
Clear depth of web (d1)	=	321.60	mm
Modulus of elasticity of steel	=	200000	MPa
Yield stress of steel	=	250	MPa

4. Calculation Of Axial Stresses

Actual compressive stress (σ_{ac},cal) = P / Ax
= 50.17E+03 / 6671.00
= 7.52 MPa

Actual bending stress @ major axis (σ_{bcx},cal) = Mx / Zxx
= 101.57E+06/ 7.79E+05
= 130.48 MPa

5. Calculation Of Permissible Stresses

Slenderness ratio in minor direction (λ_y) = l_Y / r_{yy}
= 4000 / 28.40
= 140.84

∴ From table 5.1 of IS 800 –1984

For fy = 250 Mpa

Permissible compressive stress (σ_{ac}) = 48.25 MPa > σ_{ac},cal

Hence Ok

Permissible Bending Stress :-

$T/t = 14.20/8.10 = 1.753 < 2.0$;

$d_1/t = 321.60/8.10 = 39.70 < 85$;

∴ From table 6.1B of IS 800 –1984

For $D/T = 350/14.20 = 24.64$; & $l/r_y = 4000/28.40 = 140.84$;

Permissible bending stress $((\sigma_{bcx})$ = 152.4 MPa > σ_{bcx},cal

Hence Ok

6. Check For Combine Stresses

∴ Using Cl.: 7.1.1 of IS 800 – 1984

$$\frac{\sigma_{ac,cal}}{\sigma_{ac}} + \frac{\sigma_{bcx,cal} \times C_{mx}}{\left\{1 - \frac{\sigma_{ac,cal}}{0.6 \times f_{ccx}}\right\} \times \sigma_{bcx}} + \frac{\sigma_{bcy,cal} \times C_{my}}{\left\{1 - \frac{\sigma_{ac,cal}}{0.6 \times f_{ccy}}\right\} \times \sigma_{bcy}} < 1.33$$

where $C_{mx} = 0.85$

$C_{my} = 0.85$

$f_{cc} = \Pi^2 E / \lambda^2$

$= 99.51$ MPa

$$\frac{7.52}{48.25} + \frac{130.48 \times 0.85}{\left[1 - \frac{7.52}{0.6 \times 99.51}\right] \times 152.4} = 0.844 < 1.33$$

Hence Ok

Design ratio from staad is 0.845 and manual is equal to 0844 hence staad design is verified

5.5.5.3 Check For Deflection

Table 5.22 Maximum Node Displacement

Node	Load No.	X Trans (mm)	Y Trans (mm)	Z Trans (mm)
36	112	5.780	1.926	24.854
37	112	5.777	2.255	22.925
38	112	5.770	1.777	24.056
39	112	5.795	2.638	25.573
40	112	5.814	2.610	27.485
41	112	5.819	2.300	26.260
42	112	5.822	1.870	26.588
78	112	4.660	1.531	25.102
79	112	4.656	1.578	23.159
80	112	4.645	1.120	24.292
81	112	4.660	1.535	25.829
82	112	4.672	1.479	27.727
83	112	4.680	1.511	26.503
84	112	4.684	1.185	26.830
	Maximum	5.822	2.638	27.727
	Minimum	4.645	1.120	22.925

Total height (H) = 13500 mm

Actual Deflection = 27.727 mm

Permissible defection [7] = H / 325

= 41.25 > Actual Deflection

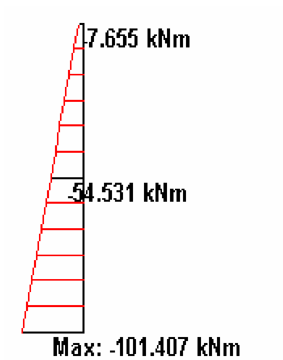
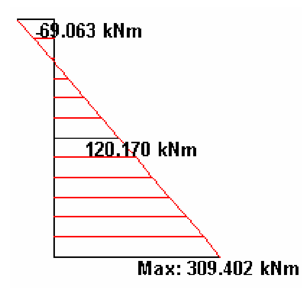
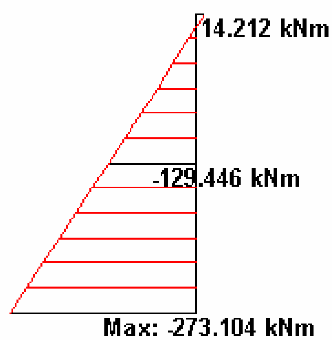
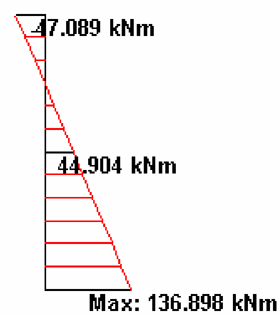
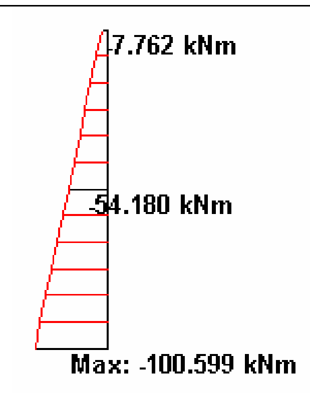
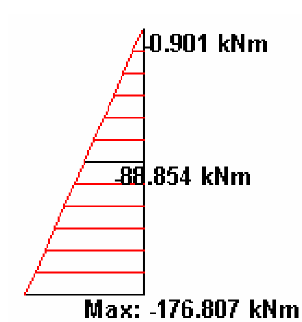
.... Hence ok

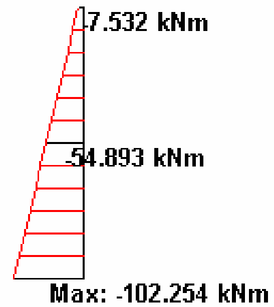
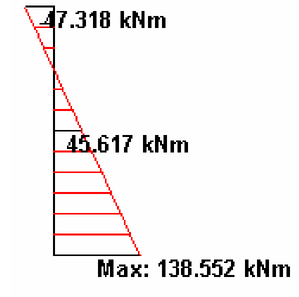
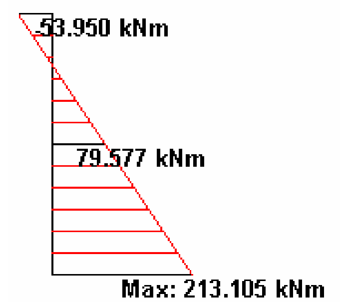
5.6 IMPACT OF VARIOUS LOADS ON DESIGN OF PIPE RACK

To study impact of various loads on design, one column and transverse beam having maximum design ratio has been selected and their behaviour for different load combination has been observe

5.6.1 Governing Load Combination for Columns Design

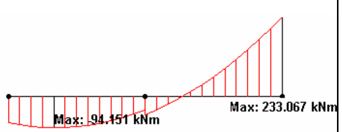
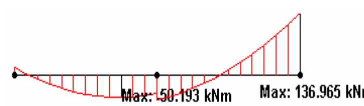
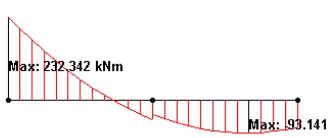
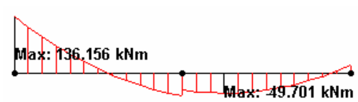
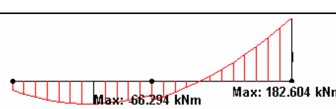
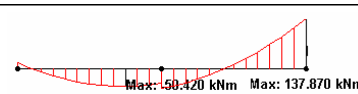
Table 5.23 B.M Diagram for Column

LOAD CASE	B.M DIAGRAM	LOAD CASE	B.M DIAGRAM
DL+LL+ P(O) + FF+AF		DL+ LL + P(O)- FF - AF- WZ	
DL+LL +P(O)+FF +AF+WZ		DL+ LL + P(O)- FF - AF- WX	
DL+ LL + P(O) + FF + AF+ WX		DL+LL +P(O)+FF +AF+VZ	

DL+ LL + P(O) + FF + AF+ VX		DL+ LL + P(O)- FF - AF- VX	
DL+ LL + P(O) - FF - AF-VZ			

5.6.2 Governing Load Combination for Beam Design

Table 5.24 B.M Diagram for Column

LOAD CASE	B.M DIAGRAM	LOAD CASE	B.M DIAGRAM
DL+LL + 10 %P(O) + FF +AF + WZ		DL+LL + 10 %P(O) + FF +AF + WX	
DL+LL + 10 %P(O) - FF -AF - WZ		DL+LL + 10 %P(O) - FF - AF - WX	
DL+LL + 10 %P(O) + FF +AF+ VZ		DL+LL + 10 %P(O) + FF +AF VX	

5.6.3 Impact Of Various Load on Design of Pipe Rack

Table 5.25 B. M. & Stress Ratio for Basic Load Case in Column

Load Case	DL + LL	Pipe Empty Load	Pipe Operating Load	Pipe Test Load	Friction Force	Anchor Force	Wind Load in Z Dir	Total
Bending Moment (kN-m)	4.49	16.49	26.11	22.92	80.73	38.81	171.69	362.29
B.M.in (%)	1.24	4.57	7.23	6.35	22.35	10.74	47.52	
Stress Ratio	0.243	0.125	0.194	0.169	0.198	0.1	0.45	

Table 5.26 B. M. & Stress Ratio for Basic Load Case in Trans Beam

Load Case	DL + LL	Pipe Empty Load	Pipe Operating Load	Pipe Test Load	Friction Force	Anchor Force	Wind Load in Z Dir	Total
Bending Moment (kN-m)	14.51	49.01	78.62	68.64	37.56	0	104.774	353.11
B.M.in (%)	4.11	13.88	22.26	19.44	10.64	0.00	29.67	
Stress Ratio	0.052	0.175	0.281	0.246	0.157	0.006	0.357	

Discussion

From above table 5.23 & 5.24, we can summarize that governing load combination for design is Pipe Operating Load - Friction Force – Anchor Force - Wind Load in Z- Direction. Further table 5.25 and 5.26 gives the impact of various basic loads and above observation we conclude that wind load is very important load as structural point of view in design of pipe rack.

6. PARAMETRIC STUDY

6.1 GENERAL

This chapter gives behaviour of steel pipe rack under variation of wind speed. As detail design of pipe rack was carried out for 50 m/s wind speed, so attempt is made to study behaviour under 39 m/s and 44 m/s wind speed keeping all other load constant.

Study also includes exercise, to optimize the utilization of existing members. Various structural configuration of pipe rack have been considered for analysis purpose as per details given below.

a) Varying section of members

b) Changing pattern of vertical bracing

6.2 WIND LOAD CALCULATION

6.2.1 Wind Load Calculation for 39 m/s Wind Speed

Location	:	Mangalore	
Basic Wind Speed, V_b	:	39 m/s	(Cl:5.2)
Risk Coefficient K_1	:	1	(Cl: 5.3.1, Table 1)
Topography factor K_3	:	1	(Cl: 5.3.3)
Terrain Category	:	Category 3	(Cl: 5.3.2.1)
Class of Structure	:	Class B	(Cl: 5.3.2.2)
Height of Structure	:	13.5 m	

K_2 Factor:

Height (m)	K_2	V_z (m/s)	P_z (N/m^2)	P_z (kN/m^2)
10.00	0.880	34.32	707	0.707
13.50	0.922	35.96	776	0.776

1. Determination of wind force coefficient, c_f

Effective Area (A_{eff}):

Table 6.1 Effective Area Calculations

Member	Breadth (m)	Length (m)	Nos.	Area (m^2)
(1)	(2)	(3)	(4)	(5)= (2) x (3) x (4)
Column – C1	0.620	5.00	2	6.20
Column – C2	0.600	2.00	2	2.40
Column – C3	0.600	2.00	2	2.40
Column – C4	0.600	3.00	2	3.60
Column – C5	0.600	1.50	2	1.80
Beam – TB1	0.550	7.50	1	4.10
Beam – TB2	0.550	7.50	1	4.10
Beam – TB3	0.550	7.50	1	4.10
Beam – TB4	0.400	7.50	1	3.00
Beam – TB5	0.450	7.50	1	3.40
		Total Effective Area		35.08

Total Area:

A_{total} = (W+C) x H

= (8 + 0.62) x 13.5

= 116.37 m^2

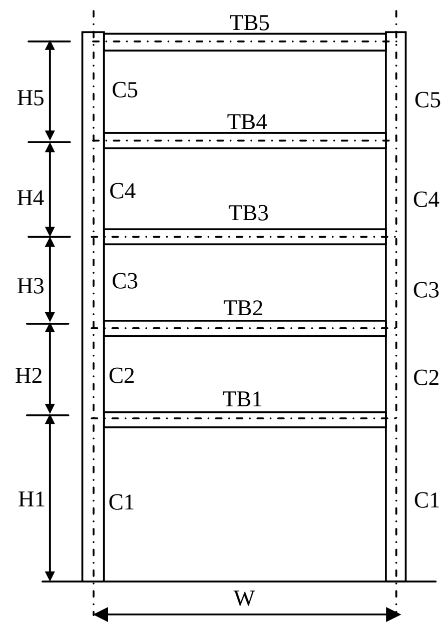


Fig. 6.1 Cross Section of Pipe Rack in Transverse Direction

Therefore,

Solidity Ratio, $\phi = A_{eff}/A_{total}$

$\phi = 0.301$

Force Coefficient (For single frame)

$C_f = 1.7$ (Cl: 6.3.3.3, Table 28)

Frame Spacing

S = 8.0 m

Least overall frame dimension

D_{min} = 8.0 m

Frame Spacing Ratio, S.R.

S.R. = S/D_{min} = 1

Number of Frames, n = 7

Effective Solidity Ratio, $\beta = \phi$ (Cl: 6.3.3.4, Table 29, IS 875)

Shielding factor, η = 0.799 (Cl: 6.3.3.3, Table 29, IS 875)

Total Force Coeff, $C_{f,total}$ = C_f (1+(n-1) x η)

= 9.84

For Succeeding Frames, $C_{f,s}$ = C_f x η

= 1.36

2. Wind Load at Different Joints (Wind in Longitudinal Direction)

On each grid L & M

Table 6.2 Wind Load in Long. Direction for 39 m/s

EL	Memb	Force	Wind Pre.	Effective area			Total wind force	
		C_f, total	P_z (kN/m^2)	Length (m)	Width (m)	Area (m^2)	F (kN)	F, total (kN)
105.0	Col	9.84	0.707	2.35	0.62	1.46	10.20	28.48
	Col	9.84	0.707	1.00	0.60	0.60	4.17	
	Beam	9.84	0.707	3.69	0.55	2.03	14.11	
107.0	Col	9.84	0.707	2.00	0.60	1.20	8.34	22.69
	Beam	9.84	0.707	3.75	0.55	2.06	14.34	
109.0	Col	9.84	0.707	2.50	0.60	1.50	10.43	24.77
	Beam	9.84	0.707	3.78	0.55	2.06	14.34	
112.0	Col	9.84	0.776	2.25	0.60	1.35	10.31	21.76
	Beam	9.84	0.776	3.75	0.40	1.50	11.45	
113.5	Col	9.84	0.776	0.75	0.60	0.45	3.44	16.32
	Beam	9.84	0.776	3.75	0.45	1.68	12.88	
				Total base shear for 39 m/s				228.04
				Total base shear for 50 m/s				374.81

3. Wind Load at Different Joints: (Wind in Transverse Direction)

Wind Force at each tier level (N)

$$F = K \times P_z \times S$$

Where,

P_z = Design wind pressure (N/m^2)

S = Spacing of portals (m)

K = Force coefficient for pipe rack (Including wind load factor for pipe)

Width of Pipe Rack	k
Upto 4 m	1.25
Above 4m upto 6m	1.50
Above 6m upto 10m	2.00
Above 10m upto 12m	2.50

Width of Pipe rack = 8 m
∴ k = 2.00

Table 6.3 Wind Load in Trans. Direction for 39 m/s

EL	Joint No.	Force coeff. $C_{f,\ total}$	Wind Pre. P_z (kN.m^2)	Spacing (m)	Wind Force F (kN)
105.00	31	2.00	0.71	8.00	11.31
	34	2.00	0.71	8.00	11.31
	38	2.00	0.71	8.00	11.31
	41	2.00	0.71	8.00	11.31
	44	2.00	0.71	8.00	11.31
	47	2.00	0.71	8.00	11.31
	50	2.00	0.71	8.00	11.31
107.00	63	2.00	0.71	8.00	11.31
	72	2.00	0.71	8.00	11.31
	76	2.00	0.71	8.00	11.31
	80	2.00	0.71	8.00	11.31
	84	2.00	0.71	8.00	11.31
	88	2.00	0.71	8.00	11.31
	92	2.00	0.71	8.00	11.31
109.00	111	2.00	0.71	8.00	11.31
	114	2.00	0.71	8.00	11.31
	121	2.00	0.71	8.00	11.31
	124	2.00	0.71	8.00	11.31
	127	2.00	0.71	8.00	11.31
	130	2.00	0.71	8.00	11.31
112.00	149	2.00	0.78	8.00	12.41
	152	2.00	0.78	8.00	12.41
	156	2.00	0.78	8.00	12.41
	162	2.00	0.78	8.00	12.41
	165	2.00	0.78	8.00	12.41
	168	2.00	0.78	8.00	12.41
113.5	171	2.00	0.78	8.00	12.41
	173	2.00	0.78	8.00	12.41
	178	2.00	0.78	8.00	12.41
	180	2.00	0.78	8.00	12.41
	182	2.00	0.78	8.00	12.41
	184	2.00	0.78	8.00	12.41
	186	2.00	0.78	8.00	12.41
			Total base shear for 39 m/s		387.51
			Total base shear for 50 m/s		636.90

4. Wind Load Calculation for Staircase

Wind Load in X- Direction

A_{eff} = 24.5 m^2
A_{total} = 104.2 m^2

Solidity ratio = $\frac{A_{eff}}{A_{total}}$ = 0.2351

Force Coefficient = 1.7649 (Cl: 6.3.3.3, Table 28)

Frame Spacing
S = 2.500 m

Least overall Frame Dimension
D_{min} = 6.000 m

Frame Spacing Ratio, S.R.
S.R. = S/D_{min}
= 0.4167

Sheilding Factor η = 0.765 (Cl: 6.3.3.3, Table 29)

For Succeeding Frames, $C_{f,s}$
= $C_f \times \eta$
= 1.3499

Wind Load on Grid M

Grid	Level (m)	Aeff (m2)	Cf	Pz (kN/m2)	Force (kN)
M	104.00	3.30	1.765	0.707	4.12
	106.00	2.19	1.765	0.707	2.73
	108.00	1.20	1.765	0.707	1.50
	110.00	2.87	1.765	0.776	3.92
	113.50	1.83	1.765	0.776	2.50
	116.00	1.14	1.765	0.776	1.55

Wind Load in Z- Direction

A_{eff} = 9.37 m^2
A_{total} = 38.36 m^2

Solidity ratio = $\frac{A_{eff}}{A_{total}}$ = 0.2443

Force Coefficient = 1.7557 (Cl: 6.3.3.3, Table 28)

Frame Spacing

S = 6.000 m

Least overall Frame Dimension

D_{min} = 2.500 m

Frame Spacing Ratio, S.R.

S.R. = S/D_{min}

= 2.4

Sheilding Factor η = 1.000 (Cl: 6.3.3.3, Table 29)

For Succeeding Frames, $C_{f,s}$

= $C_f \times \eta$

= 1.7557

Wind Load on Grid 1

Grid	Level (m)	Aeff (m^2)	Cf	Pz (kN/m^2)	Force (kN)
1					
	106.00	2.33	1.7557	0.707	2.88
	113.50	1.60	1.7557	0.776	2.18

6.2.2 Wind Load Calculation for 44 m/s Wind Speed

Location	:	Mumbai	
Basic Wind Speed, V_b	:	44 m/s	(Cl:5.2)
Risk Coefficient K_1	:	1	(Cl: 5.3.1, Table 1)
Topography factor K_3	:	1	(Cl: 5.3.3)
Terrain Category	:	Category 3	(Cl: 5.3.2.1)
Class of Structure	:	Class B	(Cl: 5.3.2.2)
Height of Structure	:	13.5 m	

K_2 Factor:

Height (m)	K_2	V_z (m/s)	P_z (N/m^2)	P_z (kN/m^2)
10.00	0.880	38.72	900	0.900
13.50	0.922	40.57	987	0.987

2. Wind Load at Different Joints (Wind in Longitudinal Direction)

On each grid L & M

Table 6.4 Wind Load in Long. Direction for 44 m/s

EL	Memb	Force	Wind Pre.	Effective area			Total wind force	
		C_f, total	P_z (kN/m^2)	Length (m)	Width (m)	Area (m^2)	F (kN)	F, total (kN)
105.0	Col	9.84	0.707	2.35	0.62	1.46	12.98	36.25
	Col	9.84	0.900	1.00	0.60	0.60	5.31	
	Beam	9.84	0.900	3.69	0.55	2.03	17.96	
107.0	Col	9.84	0.900	2.00	0.60	1.20	10.62	28.88
	Beam	9.84	0.900	3.75	0.55	2.06	18.26	
109.0	Col	9.84	0.900	2.50	0.60	1.50	13.28	31.53
	Beam	9.84	0.900	3.78	0.55	2.06	18.26	
112.0	Col	9.84	0.987	2.25	0.60	1.35	13.12	27.69
	Beam	9.84	0.987	3.75	0.40	1.50	14.57	
113.5	Col	9.84	0.987	0.75	0.60	0.45	4.37	20.77
	Beam	9.84	0.987	3.75	0.45	1.68	16.40	
				Total base shear for 44 m/s				290.30
				Total base shear for 50 m/s				374.81

3. Wind Load at Different Joints: (Wind in Transverse Direction)

Wind Force at each tier level (N)

$$F = K \times P_z \times S$$

Where,

P_z = Design wind pressure (N/m^2)

S = Spacing of portals (m)

K = Force coefficient for pipe rack (Including wind load factor for pipe)

Width of Pipe Rack	k
Upto 4 m	1.25
Above 4m upto 6m	1.50
Above 6m upto 10m	2.00
Above 10m upto 12m	2.50

Width of Pipe rack = 8 m

∴ k = 2.00

Table 6.5 Wind Load in Trans. Direction for 44 m/s

EL	Joint No.	Force coeff.	Wind Pre.	Spacing	Wind Force
		$C_{f,\ total}$	P_z (kN.m^2)	(m)	F (kN)
105.00	31	2.00	0.90	8.00	14.39
	34	2.00	0.90	8.00	14.39
	38	2.00	0.90	8.00	14.39
	41	2.00	0.90	8.00	14.39
	44	2.00	0.90	8.00	14.39
	47	2.00	0.90	8.00	14.39
	50	2.00	0.90	8.00	14.39
107.00	63	2.00	0.90	8.00	14.39
	72	2.00	0.90	8.00	14.39
	76	2.00	0.90	8.00	14.39
	80	2.00	0.90	8.00	14.39
	84	2.00	0.90	8.00	14.39
	88	2.00	0.90	8.00	14.39
	92	2.00	0.90	8.00	14.39
109.00	111	2.00	0.90	8.00	14.39
	114	2.00	0.90	8.00	14.39
	121	2.00	0.90	8.00	14.39
	124	2.00	0.90	8.00	14.39
	127	2.00	0.90	8.00	14.39
	130	2.00	0.90	8.00	14.39
112.00	149	2.00	0.99	8.00	15.80
	152	2.00	0.99	8.00	15.80
	156	2.00	0.99	8.00	15.80
	162	2.00	0.99	8.00	15.80
	165	2.00	0.99	8.00	15.80
	168	2.00	0.99	8.00	15.80
113.5	171	2.00	0.99	8.00	15.80
	173	2.00	0.99	8.00	15.80
	178	2.00	0.99	8.00	15.80
	180	2.00	0.99	8.00	15.80
	182	2.00	0.99	8.00	15.80
	184	2.00	0.99	8.00	15.80
	186	2.00	0.99	8.00	15.80
			Total base shear for 44 m/s		493.24
			Total base shear for 50 m/s		636.90

4. Wind Load Calculation for staircase

a. Wind load in x- direction

Wind load on Grid M

Grid	Level (m)	Aeff (m^2)	Cf	Pz (kN/m^2)	Force (kN)
M					
	104.00	3.30	1.765	0.900	5.24
	106.00	2.19	1.765	0.900	3.48
	108.00	1.20	1.765	0.900	1.91
	110.00	2.87	1.765	0.987	4.99
	113.50	1.83	1.765	0.987	3.18
	116.00	1.14	1.765	0.987	1.98

b. Wind load in z- direction

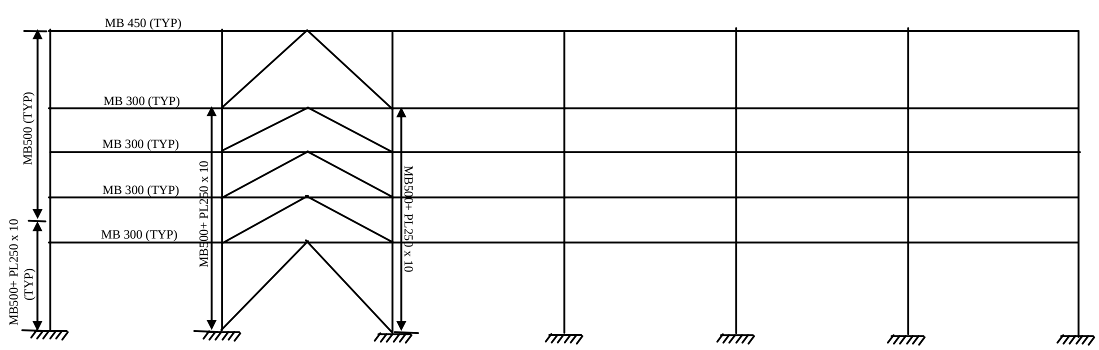
Wind load on Grid 1

Grid	Level (m)	Aeff (m^2)	Cf	Pz (kN/m^2)	Force (kN)
1					
	106.00	2.33	1.7557	0.900	3.67
	113.50	1.60	1.7557	0.987	2.77

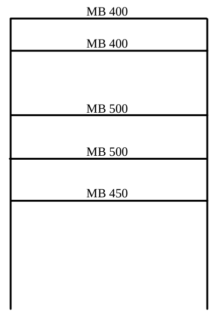
6.3 DESIGN SUMMARY

Design summary for pipe rack with different wind speed is as show below

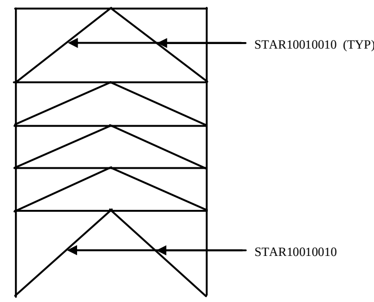
6.3.1 Design Summary for 50 m/s Wind Speed



a. Long Frame



b. Trans Frame



c. Long Frame at grid 2-3

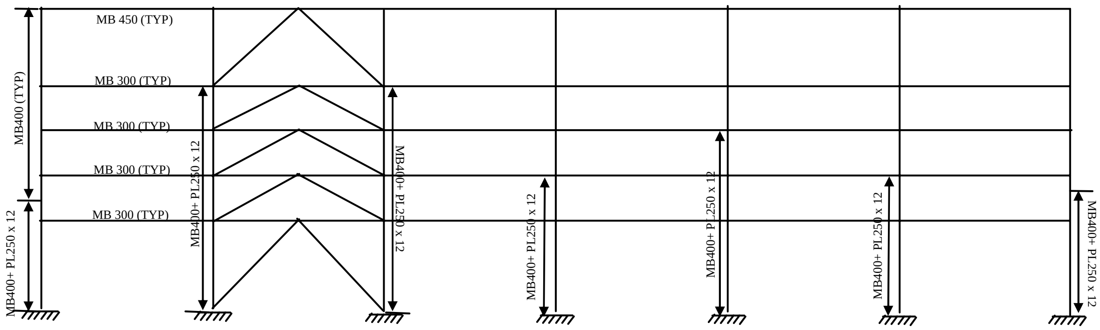
Fig. 6.2 Section used for 50 m/s Wind Speed

Design Summary

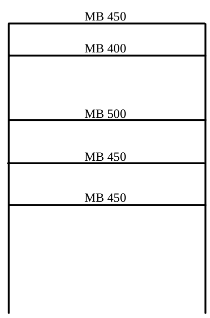
Table 6.6 Design Summary for 50 m/s Wind Speed

Sr. No	Member	Section Property	Stress Ratio		Remark
			Long Term	Short Term	
1	Column (upto EL 110.0)	ISMB 500 + 250 x 12 mm Thick plate	0.522	1.01	Ok
2	Column (Rest)	ISMB 500	0.802	0.986	Ok
3	Transverse Beams				
	At EL 105.00	ISMB 450	0.845	0.952	Ok
	At EL 107.00	ISMB 500	0.774	1.14	Ok
	At EL 109.00	ISMB 500	0.953	1.05	Ok
	At EL 113.50	ISMB 400	0.816	1.11	Ok
4	Longitudinal Beams				
	At EL 104.00	ISMB 300	0.772	0.987	Ok
	At EL 106.00	ISMB 300	0.750	0.850	Ok
	At EL 108.00	ISMB 300	0.780	0.890	Ok
	At EL 110.00	ISMB 300	0.857	0.985	Ok
	At EL 113.50	ISMB 450	0.956	1.080	Ok
5	Portal	ISMB 300	0.695	0.695	Ok
6	Vertical Bracing				
	At EL 105.00	Star 110 x 110 x 12	0.735	1.18	Ok
	Rest	Star 100 x 100 x 10	0.622	0.92	Ok
7	Plan Bracing	2ISA 90 x 90 x 8	0.419	0.438	Ok
8	Strut	2ISA 75 x 75 x 8	0.185	1.28	Ok
		2ISA 90 x 90 x 8	0.332	1.02	Ok

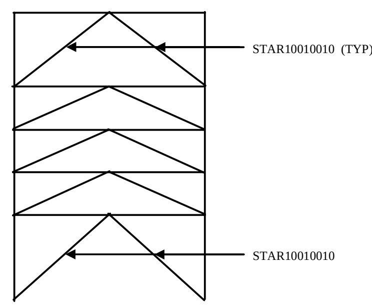
6.2.3 Design Summary for 44 m/s Wind Speed



a. Long Frame



b. Trans Frame



c. Long Frame At Grid 2-3

Fig. 6.3 Section used for 44 m/s Wind Speed

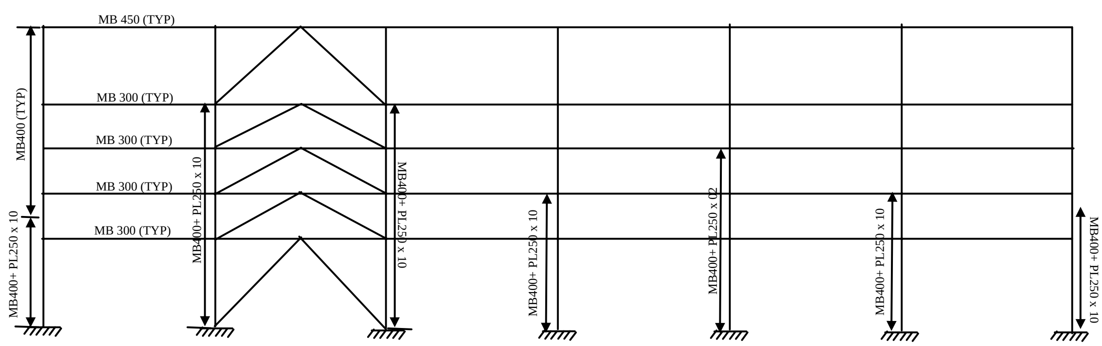
Design Summary

Table 6.7 Design Summary for 44 m/s Wind Speed

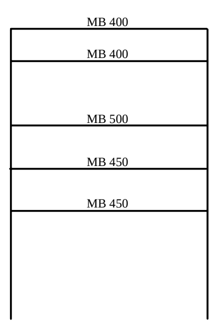
Sr. No	Member	Section Property	Stress Ratio		Remark
			Long Term	Short Term	
1	Column (upto EL 110.0)	ISMB 500 + 250 x 12 mm Thick plate	0.460	1.024	Ok
2	Column (Rest)	ISMB 400	0.932	1.257	Ok
3	Transverse Beams				
	At EL 105.00	ISMB 450	0.860	1.03	Ok
	At EL 107.00	ISMB 500	0.911	1.22	Ok
	At EL 109.00	ISMB 500	0.903	1.26	Ok
	At EL 113.50	ISMB 400	0.835	1.11	Ok

Sr. No	Member	Section Property	Stress Ratio		Remark
			Long Term	Short Term	
4	Longitudinal Beams				
	At EL 104.00	ISMB 300	0.772	0.881	Ok
	At EL 106.00	ISMB 300	0.750	0.865	Ok
	At EL 108.00	ISMB 300	0.782	0.887	Ok
	At EL 110.00	ISMB 300	0.857	0.952	Ok
	At EL 113.50	ISMB 450	0.956	1.078	Ok
5	Portal	ISMB 300	0.695	0.695	Ok
6	Vertical Bracing				
	At EL 105.00	Star 110 x 110 x 12	0.744	1.107	Ok
	Rest	Star 100 x 100 x 10	0.630	0.927	Ok
7	Plan Bracing	2ISA 65 x 65 x 6	0.787	0.815	Ok
8	Strut	2ISA 75 x 75 x 8	0.328	1.01	Ok

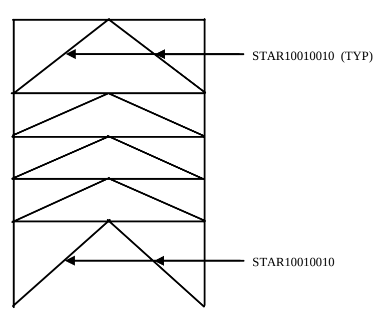
6.2.3 Design Summary for 39 m/s Wind Speed



A. Long. Frame



b. Trans Frame



c. Long Frame at grid 2-3

Fig. 6.4 Section used for 39 m/s Wind Speed

Design Summary

Table 6.8 Design Summary for 39 m/s Wind Speed

Sr. No	Member	Section Property	Stress Ratio Long Term	Stress Ratio Short Term	Remark
1	Column (upto EL 110.0)	ISMB 500 + 250 x 10 mm Thick plate	0.796	1.261	Ok
2	Column (Rest)	ISMB 400	0.958	1.230	Ok
3	Transverse Beams				
	At EL 105.00	ISMB 450	0.924	1.134	Ok
	At EL 107.00	ISMB 500	0.925	1.172	Ok
	At EL 109.00	ISMB 500	0.903	1.274	Ok
	At EL 113.50	ISMB 400	0.653	0.897	Ok
4	Longitudinal Beams				
	At EL 104.00	ISMB 300	0.772	0.856	Ok
	At EL 106.00	ISMB 300	0.750	0.841	Ok
	At EL 108.00	ISMB 300	0.782	0.890	Ok
	At EL 110.00	ISMB 300	0.856	0.934	Ok
	At EL 113.50	ISMB 450	0.956	1.078	Ok
5	Portal	ISMB 300	0.695	0.695	Ok
6	Vertical Bracing				
	At EL 105.00	Star 110 x 110 x 12	0.747	1.111	Ok
	Rest	Star 100 x 100 x 10	0.633	0.931	Ok
7	Plan Bracing	2ISA 65 x 65 x 6	0.791	0.819	Ok
8	Strut	2ISA 75 x 75 x 8	0.329	1.013	Ok

6.3 MATERIAL TAKEOFF

6.3.1 Material Takeoff for 50 M/S Wind Speed

Table 6.9 Material Takeoff for 50 m/s Wind Speed

Sr. No	Member	Section	Length	Weight	Total weight
			m	(kN/m)	kN
1	Column	ISMB500 + PL 250 x 10	90.00	1.340	120.60
		ISMB500	99.00	0.869	86.03
		Total	189.00		206.63
2	Transverse Beam	ISMB500	112.00	0.869	97.33
		ISMB450	56.00	0.725	40.57
		ISMB400	56.00	0.616	34.51
		ISMB350	56.00	0.524	29.32
		Total	280.00		201.73
3	Longitudinal Beam	ISMB500	8.00	0.869	6.95
		ISMB450	88.00	0.725	63.76
		ISMB400	16.00	0.616	9.86
		ISMB300	368.00	0.442	162.66
		Total	480.00		243.22
4	Secondary Portal	ISMB300	240.00	0.442	106.08
5	Vertical Bracing	Star 110 x 110x 12	22.63	0.393	8.89
		Star 100 x 100x 10	74.93	0.299	22.40
6	Plan Bracing	2ISA 75 x 75 x 8	203.65	0.179	36.37
7	Struts	2ISA 75 x 75 x 8	176.00	0.179	31.43
		2ISA 90 x 90 x 8	16.00	0.216	3.46
		Total	192.00		34.89
		Total	**1442.21**		**860.22**

Total material take off for 50 m/s wind speed = **86.02 MT (1.79 MT/m)**

6.3.2 Material Take Off for 44 m/s Wind Speed

Table 6.10 Material Takeoff for 44 m/s Wind Speed

Sr No	Member	Section.	Length	Weight	Total weight
			m	(kN/m)	kN
1	Column	ISMB400 + PL 250 x 10	120.00	1.080	129.60
		ISMB400	69.00	0.869	59.96
		Total	189.00		189.56
2	Transverse Beam	ISMB500	68.00	0869	59.09
		ISMB450	100.00	0.725	72.45
		ISMB400	56.00	0.616	34.51
		ISMB350	56.00	0.524	29.32
		Total	280.00		195.37
3	Longitudinal Beam	ISMB500	8.00	0.869	6.95
		ISMB450	88.00	0.725	63.76
		ISMB400	16.00	0.616	9.86
		ISMB300	368.00	0.442	162.66
		Total	480.00		243.22
4	Secondary Portal	ISMB300	240.00	0.442	106.08
5	Vertical Bracing	Star 110 x 110x 12	22.63	0.393	8.89
		Star 100 x 100x 10	74.93	0.299	22.40
6	Plan Bracing	2ISA 65 x 65 x 6	203.65	0.117	23.79
7	Struts	2ISA 75 x 75 x 8	168.00	0.179	30.00
		2ISA 90 x 90 x 8	24.00	0.216	5.19
		Total	192.00		35.19
		Total	**1442.21**		**824.51**

Total material take off for 44 m/s wind speed = **82.45 MT (1.71 MT/m)**

6.3.3 Material Take Off for 39 m/s Wind Speed

Table 6.11 Material Takeoff for 39 m/s Wind Speed

Sr No	Member	Section.	Length	Weight	Total weight
			m	(kN/m)	kN
1	Column	ISMB400 + PL 250 x 10	118	1.008	118.94
		ISMB400	71	0.616	43.75
		Total	189.00		162.70
2	Transverse Beam	ISMB500	64.00	0869	55.62
		ISMB450	56.00	0.724	40.57
		ISMB400	104.00	0.616	64.09
		ISMB350	56.00	0.523	29.32
		Total	224.00		189.59
3	Longitudinal Beam	ISMB500	8.00	0.869	6.95
		ISMB450	88.00	0.725	63.76
		ISMB400	16.00	0.616	9.86
		ISMB300	368.00	0.442	162.66
		Total	480.00		243.22
4	Secondary Portal	ISMB300	240	0.442	106.08
5	Vertical Bracing	Star 110 x 110x 12	22.628	0.393	8.89
		Star 100 x 100x 10	74.93	0.299	22.40
6	Plan Bracing	2ISA 65 x 65 x 6	203.652	0.1168	23.79
7	Struts	2ISA 75 x 75 x 8	168.00	0.1786	30.00
		2ISA 90 x 90 x 8	24.00	0.216	5.19
		Total	192.00		35.19
		Total	1386.21		791.87

Total material take off for 39 m/s wind speed = **79.18 MT (1.65 MT/m)**

6.3.4 Summary of Material Takeoff

Table 6.12 Summary of Material Takeoff

Sr.No	Member	MTO for different Wind Speed			Difference in MTO	
		50 m/s	44 m/s	39 m/s	50-44	50-39
1	Column	20.66	18.96	16.27	1.71	4.39
2	Transverse Beam	20.17	19.54	18.96	0.64	1.21
3	Longitudinal Beam	24.32	24.32	24.32	0.00	0.00
4	Secondary Portal	10.61	10.61	10.61	0.00	0.00
5	Vertical Bracing	3.13	3.13	3.13	0.00	0.00
6	Plan Bracing	3.64	2.38	2.38	1.26	1.26
7	Struts	3.52	3.52	3.52	0.00	0.00
	Total	86.05	82.45	79.19	3.60	6.87
			Percentage change		**4.2 %**	**7.98 %**

6.4 VARIATION IN SECTION

6.4.1 Vertical Bracing

Force = 379 kN

Length = 5.66 m

Max allowable stress = 150 n/mm^2 (0.6 f_y)

Table 6.13 Variation in Section for Vertical Bracing

Section	C/S Area mm^2	λ L/r_{min}	σ_{actual} N/mm^2	$\sigma_{permissible}$ N/mm^2	Stress Ratio	Remark
Star Angel						
ISA 110x110x12	5000	96.16	75.8	83.3	0.910	
Double Angle						
2ISA 150x150x10	5810	102.29	65.23	78	0.836	l_{eff} =L
2ISA 130x130x10	5010	98.2	75.6	82.8	0.913	l_{eff} =L/2
Single Angle						
ISA 200x200x18	6881	123.28	55.07	61.3	0.898	l_{eff} =L
ISA 200x200x12	4661	91.44	81.31	89.56	0.908	l_{eff} =L/2
Channel Section						
2ISMC 250 (B/B)	7730	130.65	49.03	56.25	0.872	

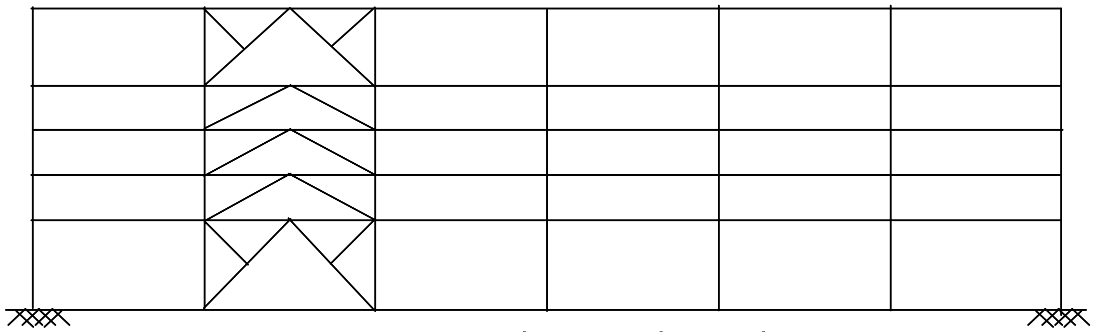


Fig 6.5. Vertical Bracing (L_{eff} = L)

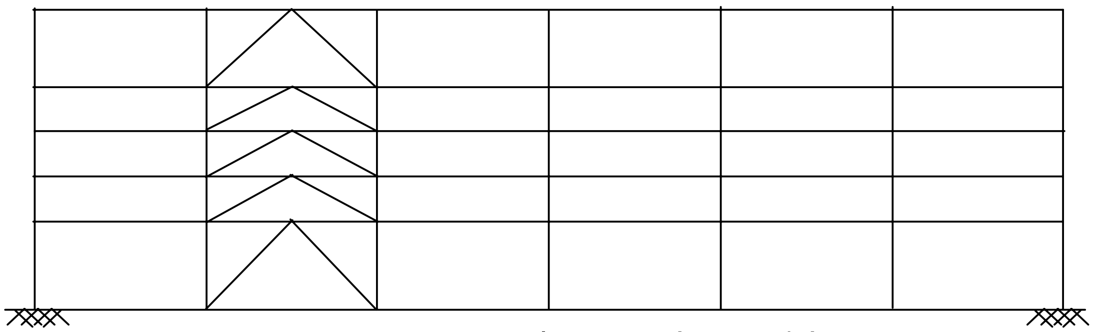


Fig 6.6. Vertical Bracing (L_{eff} = L/2)

6.4.2. Transverse Beams

Length = 8 m

Max allowable stress:-

Axial stress = 0.6 f_y

Bending stress = 0.66 f_y

1. Long Term Case

	Long Term
Axial (Fx) kN	54.56 (C)
Bending Moment kNm	87.83

Table 6.14A. Variation in Section for Transverse Beam

Section	C/S Area	Actual Stress		Per. Stress		Ratio
	mm^2	σ_{ac}	σ_{bc}	σ_{ac}	σ_{bc}	
I Section						
ISMB 400	7864	6.96	85.87	49.55	101.53	0.986
ISMB200 +PL160x16	8353	6.54	123.9	77.08	137.91	0.923
Channel Section						
2ISMC175 (F/F)	4876	5.46	127.55	76.72	143.4	0.961
2ISMC 225 (B/B)	6602	5.91	120.17	69.15	134.53	0.978
Box Section						
300 x 180	9128	5.97	103.52	67.72	119.19	0.983

2. Short Term Case

	Long Term
Axial (Fx) kN	55.94 (C)
Bending Moment kNm	118.32

Table 6.14B Variation in Section for Transverse Beam

Section	C/S Area	Actual Stress		Per. Stress		Ratio
	mm^2	σ_{ac}	σ_{bc}	σ_{ac}	σ_{bc}	
I Section						
ISMB 400	7864	7.13	115.67	65.60	135.03	0.96
ISMB200 +PL160x16	8353	6.70	167.01	102.52	183.42	0.98
Channel Section						
2ISMC175 (F/F)	4876	5.60	171.83	102.04	190.72	0.96
2ISMC 225 (B/B)	6602	6.06	161.89	91.97	178.92	0.97
Box Section						
300 x 180	9128	6.13	139.46	90.07	156.52	0.95

6.4.3 Column

Length = 8 m

Max allowable stress:-

Axial stress = 0.6 f_y

Bending stress = 0.66 f_y

1. Long Term Case

	Long Term
Axial (Fy) kN	611.48 (C)
Bending Moment kNm	102.00

Table 6.15A. Variation in Section for Column

Section	C/S Area	Actual Stress		Per. Stress		Ratio
	mm^2	σ_{ac}	σ_{bc}	σ_{ac}	σ_{bc}	
I Section						
ISMB 600	15621	39.15	33.33	83.26	124.7	0.74
ISMB450 +PL250x10	14227	43.00	42.17	99.35	131.90	0.75
Box Section						
350 x 200	10732	38.87	52.10	102.31	142.81	0.74

2. Short Term Case

	Long Term
Axial (Fy) kN	760.6 (C)
Bending Moment kNm	233.23

Table 6.15A. Variation in Section for Column

Section	C/S Area	Actual Stress		Per. Stress		Ratio
	mm^2	σ_{ac}	σ_{bc}	σ_{ac}	σ_{bc}	
I Section						
ISMB 600	15621	48.70	76.21	110.74	165.85	0.90
ISMB450 +PL250x10	14227	53.47	96.42	132.14	175.43	0.95
Box Section						
350 x 200	10732	48.35	119.13	136.07	189.94	0.98

6.5 CHANGING VERTICAL BRACING PATTERN

Vertical bracing pattern has been change with an aim to achieve economy. Different bracing pattern consider for study are as follows

a) K – Bracing
b) Knee – bracing
c) Diagonal Bracing

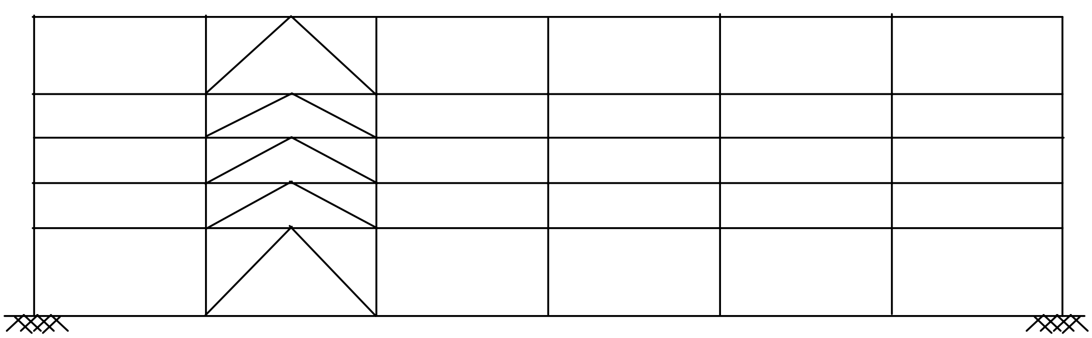


Fig 6.7. K- Bracing

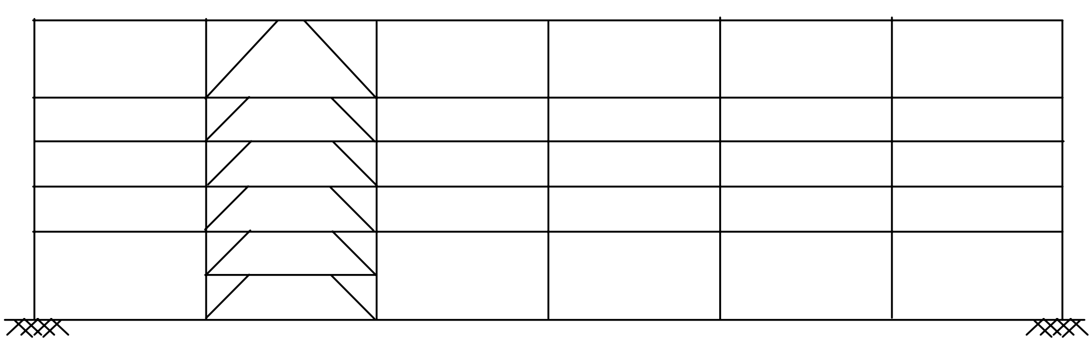


Fig 6.8 Knee Bracing

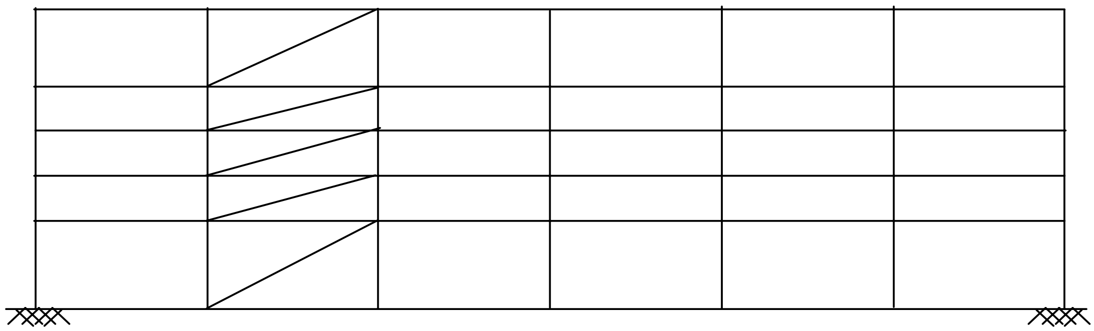


Fig 6.9 Diagonal Bracing

6.5.1 Utilization Ratio for Different Bracing Patterns

Table 6.16 Utilization Ratios for different bracing patterns

Bracing Pattern	Section	Length (m)	λ	Actual Stress (Mpa)	Permissible Stress (Mpa)	Ratio
K-Bracing	Star Angle ISA 100x100x10	4.47	98.9	75.9	81.5	0.931
Knee Bracing	Star Angle ISA90x90x8	2.83	69.4	119.2	121.5	0.985
Diagonal Bracing	Channel Section ISMC 300	8.25	290.4	6.2	49.6	Fail in Slenderness

6.5.2 Deflection of Pipe Rack Using Different Bracing Patterns

Table 6.17 Deflections for Different Bracing Patterns

Level ↓ / Bracing Pattern →	Deflection in mm		
	K- Bracing	Knee Bracing	Diagonal Bracing
EL 100.00	0	0	0
EL 104.00	11.445	11.335	14.028
EL 105.00	14.665	14.516	18.664
EL 106.00	17.406	17.301	22.301
EL 107.00	19.823	19.632	25.650
EL 108.00	21.737	21.507	28.352
EL 109.00	23.947	23.307	21.250
EL 110.00	24.976	24.693	34.204
EL 112.00	27.976	27.77	39.254
EL 113.50	29.638	29.501	41.623

Graphical Representation

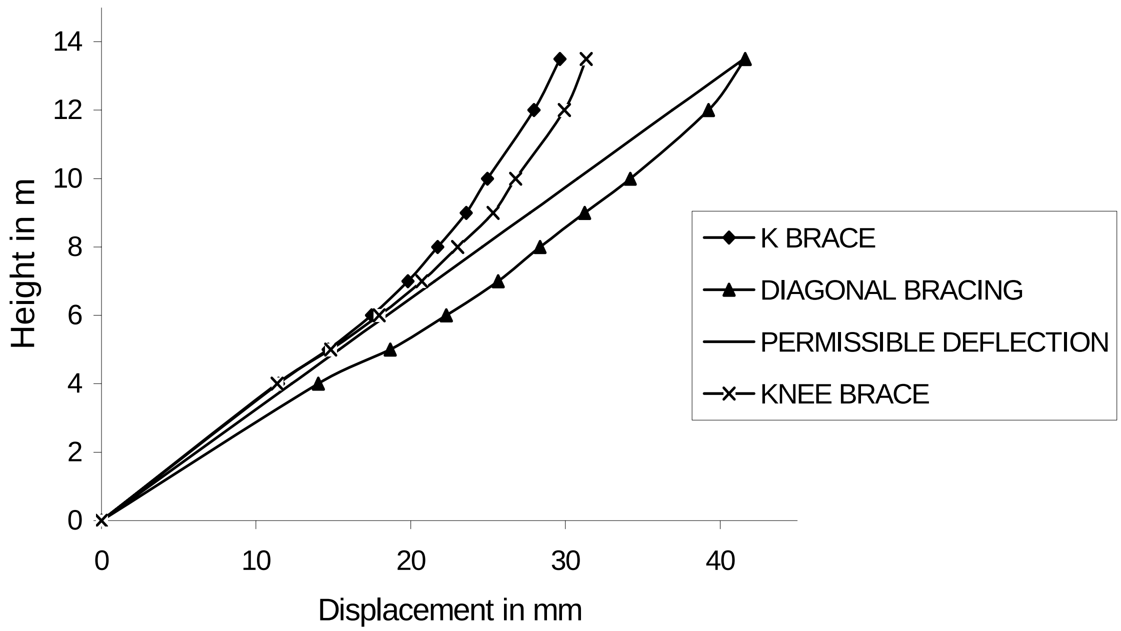


Fig 6.10 Deflections for Different Bracing Patterns (Def^n vs. Height)

Discussion:-

1. Reduction in base shear for variation in wind speed from 50 m/s to 44 m/s is 22.5% and that for 50 m/s to 39 m/s is 40 %.

2. Study has been carried out to compare MTO of pipe rack, considering variation in basic wind speeds. Following are the observation.

   a. MTO for pipe rack for wind sped 50 m/s is 86.02 MT.

   b. MTO for pipe rack for wind sped 44 m/s is 82.45 MT.

   c. MTO for pipe rack for wind sped 50 m/s is 79.18 MT.

   d. Due to reduction in wind speed from 50 m/s to 44 m/s gives reduction in base shear upto 22.5% subsequently difference in MTO is upto 4.2%.

   e. Due to reduction in wind speed from 50 m/s to 39 m/s gives reduction in base shear upto 40% subsequently difference in MTO is upto 7.89%.

3. From above exercise it can be observed that maximum utilization ratio achieved in case of vertical bracing is for Star Angle (without change in

geometry) and if geometry is changed (i.e. length is divided into two halves) than maximum utilization ratio achieved is for Double Angle.

4. For transverse beam and column, maximum utilization ratio is achieved was for Box Section but as due to connection problem and also increased in site activity, I section with plate has been used for further design.

5. Knee Bracing gives maximum utilization ratio. Here we can not use X-bracing pattern as pipes are entering and leaving pipe race through longitudinal direction.

6. From graph it is observed that, deflection for K – bracing pattern is in acceptable limits (as per code specification) and so K – bracing is preferred.

7. Deflection in case of diagonal bracing exceeds the permissible deflection. And also it is practically difficult to use diagonal bracing due to large inclination.

7. SUMMARY AND FUTURE SCOPE OF WORK

7.1 SUMMARY

Pipe racks are present in each and every refinery, they are required to carry pipelines, electrical and instrument ducts, PSV's etc. Here attempt is made to study behaviour of pipe rack. Steel pipe rack of 144 m length, along grid L,M and between grids 1 to 21 has been taken under study, considering three stretches of 48 is each. Here in this piece of work one stretch of 48 meter is analysis and design with detail structural drawings.

Petrochemical plant layout for particular capacity may be similar depending on process licenser and plot size availability. If same capacity plant with same layout is to be used then only change is in topography, which effects in terms of variation in wind speed and earthquake zone. Hence an attempt is made to study behaviour of pipe rack with variation in wind speed, pipe rack with all other factors constant is designed for three different wind speed i.e 39 m/s, 40 m/s and 50 m/s. Material take off for all three different wind speed is also work out. Further study has been carried out to understand the selection of various sections and patterns for bracing.

7.2 CONCLUSION

1. In case of structural steel pipe racks in almost all cases, wind load with pipe operating load is governing load combination for design of members.
2. Study carried out to compare wind force coefficient given in project specification with IS code and ASCE guidelines. It can be concluded that force coefficient given by project specification is on conservative side when compare with ASCE guidelines and according Indian standards (IS-875-1987) is in acceptable limit.
3. Major contribution in bending moment and utilization ratio for beams and columns is due to wind load.
4. Reduction in base shear for variation in wind speed from 50 m/s to 44 m/s is 22.5% and that for 50 m/s to 39 m/s is 40 %.

5. Study has been carried out to compare MTO of pipe rack, considering variation in basic wind speeds. Following are the observation.

   a. MTO for pipe rack for wind sped 50 m/s is 86.02 MT.
   b. MTO for pipe rack for wind sped 44 m/s is 82.45 MT.
   c. MTO for pipe rack for wind sped 50 m/s is 79.18 MT.
   d. Due to reduction in wind speed from 50 m/s to 44 m/s gives reduction in base shear upto 22.5% subsequently difference in MTO is upto 4.2%.
   e. Due to reduction in wind speed from 50 m/s to 39 m/s gives reduction in base shear upto 40% subsequently difference in MTO is upto 7.89%.

6. From above exercise it can be observed that maximum utilization ratio achieved in case of vertical bracing is for Star Angle (without change in geometry) and if geometry is changed (i.e. length is divided into two halves) than maximum utilization ratio achieved is for Double Angle.
7. For transverse beam and column, maximum utilization ratio is achieved was for Box Section but as due to connection problem and also increased in site activity, I section with plate has been used for further design.
8. Knee Bracing gives maximum utilization ratio. Here we can not use X-bracing pattern as pipes are entering and leaving pipe race through longitudinal direction.
9. From graph it is observed that, deflection for K – bracing pattern is in acceptable limits (as per code specification) and so K – bracing is preferred.
10. Deflection in case of diagonal bracing exceeds the permissible deflection. And also it is practically difficult to use diagonal bracing due to large inclination.

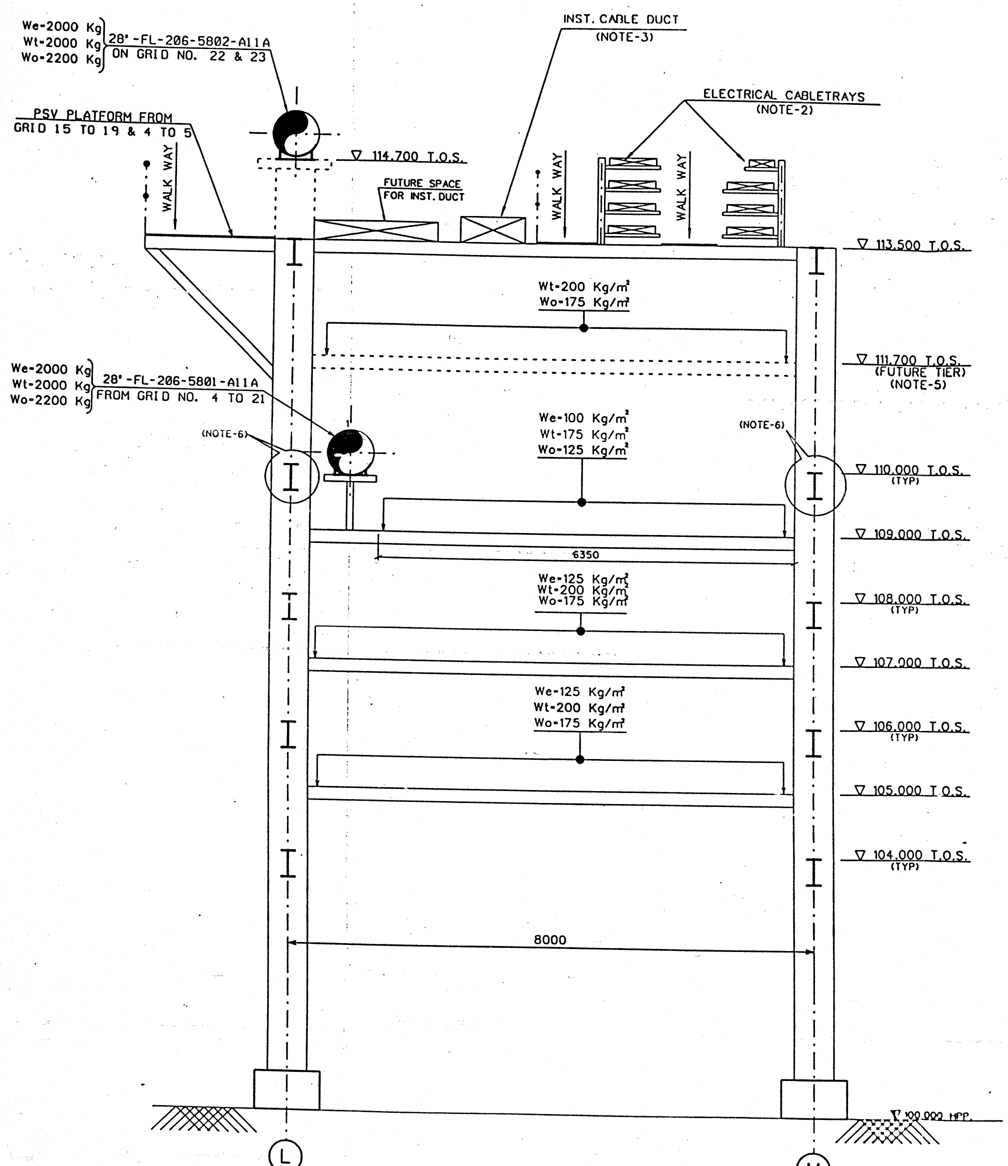
7.3 FUTURE SCOPE OF WORK

1. In this study, only pipe rack superstructure has been considered. Study can further be extended to study effect of wind and superstructure changes on foundation design.
2. Same study can be carried out considering variation in seismic zone and its effects on design of pipe rack.
3. In case of fireproofing, R.C.C. can be used instead of steel i.e. R.C.C. structure upto fireproofing level and steel structure above fire proofing level. Therefore cost comparison can be done between both cases.

Piping load input consists of pipe load on different level of pipe rack for empty, test and operating conditions and anchor loads at different levels.

1. Uniform piping load on pipe rack for grid 1 - 23
2. Anchor load on pipe rack at level 105.00 & 107.00 m
3. Anchor load on pipe rack at level 109.00 & 113.50 m

DWG. NO.



FROM GRID 1 TO 23

NOTES:-

1 ALL DIMENSIONS ARE IN mm & ELEVATIONS ARE IN METER
2 FOR TRAY SYSTEM DESIGN, IN ADDITION TO SELF LOAD & WIND FORCES FOLLOWING GUIDELINCE SHALL BE CONSIDERED.
   (a) SUPPORT SPAN - 3000mm.
   (b) CABLE LOAD - 75 Kg / LINEAR METER
   IN ADDITION TO THIS 75 Kg CONCENTRATED LOAD AT CENTER SPAN SHALL BE CONSIDERED.
3 INST. DUCT LOAD
   FROM GRID 1 TO 4 :- 850 Kg/m
   FROM GRID 4 TO 14 :- 700 Kg/m
   FROM GRID 14 TO 22 :- 700 Kg/m
   INCLUDING BOTTOM SUPPORT
4 PIPE LOADING ON LONGITUDINAL BEAMS OF PIPE RACK SHALL BE AS PER STRUCTURAL DESIGN REQUIREMENTS OF ITB.
5 PIPE RACK SUPPORTING FOR TRANSFER LINES & TWO PHASE FLOW LINES SHALL BE AS PER STRUCTURAL DESIGN REQUIREMENTS OF ITB.
6 BETWEEN GRID 7 & 8 AND 14 & 15, LONGITUDINAL BEAM AT T.O.S. EL. 110.000 SHALL BE PLACED AT T.O.S.EL. 111.700

LEGEND:-

We	-	EMPTY PIPE LOAD
Wt	-	TEST LOAD
Wo	-	OPERATING LOAD
T.O.S.	-	TOP OF STEEL
HPP.	-	HIGHEST PAVED POINT
∇	-	ELEVATION

DRAWING NO.	DRAWING TITLE	REV.
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REFERENCE DOCUMENTS/DRAWINGS

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SCH. DATE OF SUBMISSION / /

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STATEMENT OF SUB: 1st 2nd 3rd

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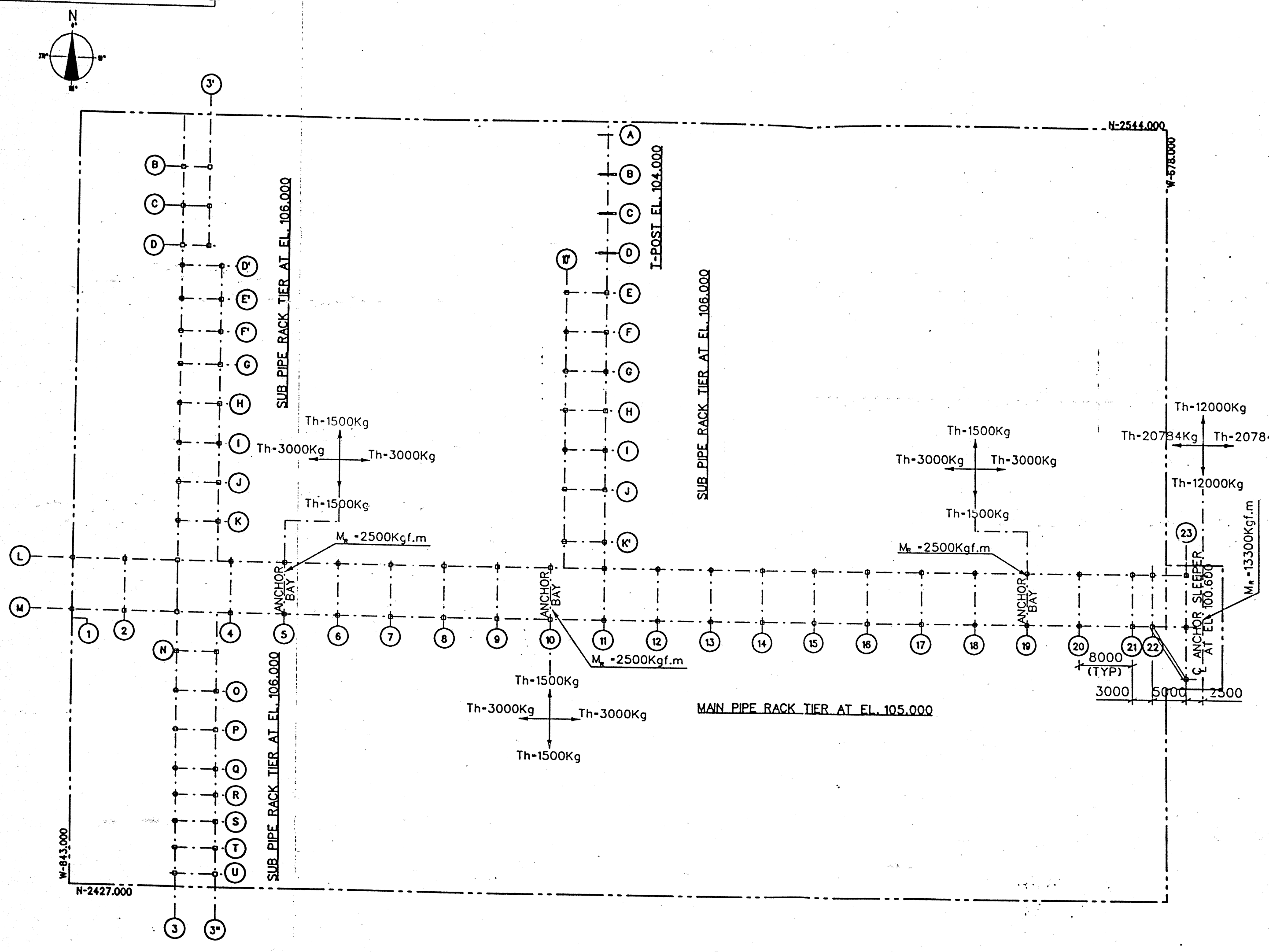
Appendix A

DETAILED ENGINEERING SUB CONTRACTOR: **L&T-CHIYODA LIMITED.** BARODA, INDIA.

DATE	SCALE	TITLE:
27/03/2002	1:1 NTS	UNIFORM PIPING LOAD ON PIPE RACK
DEPT: PIPING		

	PROJECT:	DRG. NO.:	
DRN BY: [signature]	CPCL RFE III	ANNEXURE-B TO	SH. 1 OF 4
CHK BY: [signature]	PWO NO.: CIR00009	4814-206-0-D-4-213	REV. NO. 0
APP BY: [signature]	CAD	FILE: RACKSEC LOAD CIVIL.DGN	

DWG. NO.



NOTES:-

1) ALL DIMENSIONS ARE IN mm. ELEVATIONS & CO-ORDINATES ARE IN METERS.

LEGEND:-

Th - THRUST LOAD

M_R - RESULTANT MOMENT

4814-206-0-D-4-212	CROS. VIEW OF P.R. FOR JUSTIFING P.R. WIDTH	1
DRAWING NO.	DRAWING TITLE	REV.

REFERENCE DOCUMENTS/DRAWINGS

DRG. CATEGORY: (USE TICK MARK) R I — EIL 's REVIEW CODE: — VPTL NO.:

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0	FIRST ISSUE	27/03/02	[signature]	[signature]	[signature]

DETAILED ENGINEERING SUB CONTRACTOR: **L&T-CHIYODA LIMITED.** BARODA, INDIA.

DATE 27/03/2002	SCALE 1:NTS	TITLE: ANCHOR LOAD ON PIPE RACK
DEPT: PIPING		
DRN BY: [signature]	PROJECT: CPCL REF-III	DRG. NO.: ANNEXURE-C TO 4814-206-0-D-4-213 — SH. 1 OF 4
CHK BY: [signature]	PWO NO.: CIR00009	REV. NO. 0
APP BY: [signature]	CAD REVISE THIS DWG. USING CAD SYSTEM ONLY	FILE: RACKPLAN LOAD CIVIL.DGN

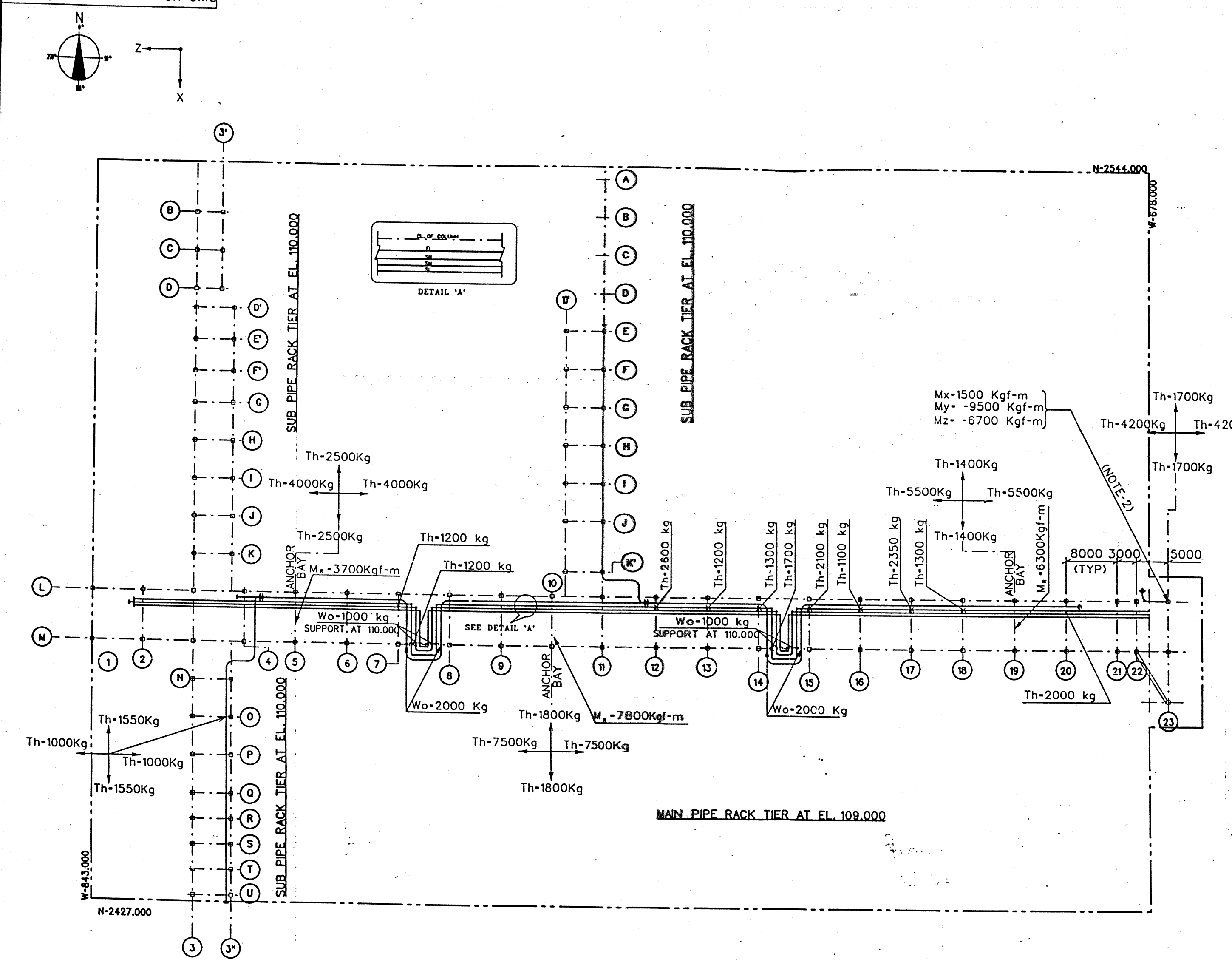
DWG. NO.

NOTES:-

1) ALL DIMENSIONS ARE IN MM. ELEVATIONS & CO-ORDINATES ARE IN METERS.
2) LOAD DUE TO ANCHOR AT WP.EL. 114.730 FOR FLARE LINE
3) ON MAIN RACK EXCEPT AT ANCHOR BAY ALL THRUST LOAD ARE GUIDE LOADS.

LEGEND:-

Th - THRUST LOAD
M_R - RESULTANT MOMENT



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REFERENCE DOCUMENTS/DRAWINGS

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DETAILED ENGINEERING SUB CONTRACTOR:	L&T - CHIYODA LIMITED. BARODA, INDIA.		
DATE 27/03/2002	SCALE 1 : NTS	TITLE: ANCHOR LOAD ON PIPE RACK	
DEPT: PIPING			
DRN BY: [signature]	PROJECT: CPCL REF-III	DRG. NO.: ANNEXURE-C TO 4814-206-0-D-4-213	SH.3 OF 4
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APP BY: [signature]	CAD	FILE: RACKPLAN LOAD CIVIL.DGN	

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MEMBER INCIDENCES
1 1 114; 2 2 115; 3 3 116; 4 4 117; 5 5 118; 6 6 119; 7 7 120;
8 114 115; 9 115 147; 10 116 117; 11 117 118; 12 118 119; 13 119 120;
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14 8 121; 15 9 122; 16 10 123; 17 11 124; 18 12 125; 19 13 126;
20 14 127; 21 122 121; 22 148 122; 23 124 123; 24 125 124; 25 126 125;
26 127 126; 27 15 128; 28 16 129; 29 17 130; 30 18 131; 31 19 132;
32 20 133; 33 21 134; 34 128 129; 35 129 149; 36 130 131; 37 131 132;
38 132 133; 39 133 134; 40 22 135; 41 23 136; 42 24 137; 43 25 138;
44 26 139; 45 27 140; 46 28 141; 47 135 136; 48 136 150; 49 137 138;
50 138 139; 51 139 140; 52 140 141; 53 29 36; 54 30 37; 55 31 38;
56 32 39; 57 33 40; 58 34 41; 59 35 42; 60 36 37; 61 37 151; 62 38 39;
63 39 40; 64 40 41; 65 41 42; 66 43 86; 67 44 87; 68 45 88; 69 46 89;
70 47 90; 71 48 91; 72 49 92; 73 86 87; 74 87 142; 75 88 89; 76 89 90;
77 90 91; 78 91 92; 79 8 157; 80 9 158; 81 10 159; 82 11 160; 83 12 161;
84 13 162; 85 14 163; 86 50 93; 87 51 94; 88 52 95; 89 53 96; 90 54 97;
91 55 98; 92 56 99; 93 93 94; 94 94 143; 95 95 96; 96 96 97; 97 97 98;
98 98 99; 99 15 164; 100 16 165; 101 17 166; 102 18 167; 103 19 168;
104 20 169; 105 21 170; 106 57 100; 107 58 101; 108 59 102; 109 60 103;
110 61 104; 111 62 105; 112 63 106; 113 100 101; 114 101 144;
115 102 103; 116 103 104; 117 104 105; 118 105 106; 119 22 171;
120 23 172; 121 24 173; 122 25 174; 123 26 175; 124 27 176; 125 28 177;
126 64 107; 127 65 108; 128 66 109; 129 67 110; 130 68 111; 131 69 112;
132 70 113; 133 107 108; 134 108 145; 135 109 110; 136 110 111;
137 111 112; 138 112 113; 139 29 178; 140 30 179; 141 31 180;
142 32 181; 143 33 182; 144 34 183; 145 35 184; 146 71 78; 147 72 79;
148 73 80; 149 74 81; 150 75 82; 151 76 83; 152 77 84; 153 78 79;
154 79 146; 155 80 81; 156 81 82; 157 82 83; 158 83 84; 159 36 78;
160 37 79; 161 38 80; 162 39 81; 163 40 82; 164 41 83; 165 42 84;
166 86 50; 167 87 51; 168 88 52; 169 89 53; 170 90 54; 171 91 55;
172 92 56; 173 93 57; 174 94 58; 175 95 59; 176 96 60; 177 97 61;
178 98 62; 179 99 63; 180 100 64; 181 101 65; 182 102 66; 183 103 67;
184 104 68; 185 105 69; 186 106 70; 187 107 71; 188 108 72; 189 109 73;
190 110 74; 191 111 75; 192 112 76; 193 113 77; 194 114 8; 195 115 9;
196 116 10; 197 117 11; 198 118 12; 199 119 13; 200 120 14; 201 121 15;
220 140 34; 221 141 35; 222 142 88; 223 143 95; 224 144 102;
225 145 109; 226 146 80; 227 147 116; 228 123 148; 229 149 130;
230 150 137; 231 151 38; 232 2 147; 233 3 147; 234 115 148; 235 116 148;
236 122 149; 237 123 149; 238 129 150; 239 130 150; 240 136 151;
241 137 151; 242 44 142; 243 45 142; 244 87 143; 245 88 143; 246 94 144;
247 95 144; 248 101 145; 249 102 145; 250 108 146; 251 109 146;
252 9 152; 253 10 152; 254 152 51; 255 152 52; 256 16 153; 257 17 153;
258 153 58; 259 153 59; 260 23 154; 261 24 154; 262 65 154; 263 66 154;
264 30 155; 265 31 155; 266 72 155; 267 73 155; 268 37 156; 269 38 156;
270 79 156; 271 156 80; 272 157 50; 273 158 51; 274 159 52; 275 160 53;
276 161 54; 277 162 55; 278 163 56; 279 164 57; 280 165 58; 281 166 59;
282 167 60; 283 168 61; 284 169 62; 285 170 63; 286 171 64; 287 172 65;
294 179 72; 295 180 73; 296 181 74; 297 182 75; 298 183 76; 299 184 77;
300 157 158; 301 158 152; 302 159 160; 303 160 161; 304 152 159;
305 161 162; 306 162 163; 307 164 165; 308 165 153; 309 166 185;
310 167 186; 311 153 166; 312 168 187; 313 169 188; 314 171 172;
315 172 154; 316 173 174; 317 174 175; 318 154 173; 319 175 176;

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320 176 177; 321 178 179; 322 179 155; 323 180 181; 324 181 182;
325 155 180; 326 182 183; 327 183 184; 328 17 185; 329 60 185;
330 185 167; 331 185 59; 332 18 185; 333 18 186; 334 61 186;
335 186 168; 336 19 186; 337 60 186; 338 19 187; 339 62 187;
340 187 169; 341 20 187; 342 61 187; 343 20 188; 344 63 188;
345 188 170; 346 21 188; 347 62 188;
*-------------------------------------------------------------------------------*
START USER TABLE
TABLE 1
UNIT CM KN
GENERAL
STAR11011012
50.04 11 1.2 11 1.2 1229.5 1229.5 1 111.77 111.77 25.02 25.02 0 0 0 0
STAR10010010
38.06 10 1 10 1 778.6 778.6 1 77.86 77.86 19.03 19.03 0 0 0 0
END
*-------------------------------------------------------------------------------*
START GROUP DEFINITION
GEOMETRY
_TRBEAM_105 79 TO 85 272 TO 278
_TRBEAM_107 99 TO 105 279 TO 285
_TRBEAM_109 119 TO 125 286 TO 292
_TRBEAM_112 139 TO 145 293 TO 299
_TRBEAM_113.5 159 TO 165
_LONGBEAM_104 8 TO 13 73 TO 78 222 227
_LONGBEAM_106 21 TO 26 93 TO 98 223 228
_LONGBEAM_108 34 TO 39 113 TO 118 224 229
_LONGBEAM_110 47 TO 52 133 TO 138 225 230
_LONGBEAM_113.5 60 TO 65 153 TO 158 226 231
_HOR_BR 252 TO 271 328 329 331 TO 334 336 TO 339 341 TO 344 346 347
_VER_BR100 232 233 242 243
_VER_BR104 234 235 244 245
_VER_BR106 236 237 246 247
_VER_BR108 238 239 248 249
_VER_BR110 240 241 250 251
_COL_104-105 1 TO 7 66 TO 72 166 TO 172 194 TO 200
_COL_100 1 TO 7 66 TO 72
_COL_104 166 TO 172 194 TO 200
_COL_105 14 TO 20 86 TO 92
_COL_106 173 TO 179 201 TO 207
_COL_107 27 TO 33 106 TO 112
_COL_108 180 TO 186 208 TO 214
_COL_109 40 TO 46 126 TO 132
_COL_110 187 TO 193 215 TO 221
_COL_112 53 TO 59 146 TO 152
_STRUT 300 TO 327 330 335 340 345
END GROUP DEFINITION
*-------------------------------------------------------------------------------*
```

```
UNIT METER KN
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.05e+008
POISSON 0.3
DENSITY 78.5
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
*----------------------------------------------------------------------------------*
MEMBER PROPERTY INDIAN
_COL_100 TABLE TB ISMB500 WP 0.25 TH 0.012
_COL_104 TABLE TB ISMB500 WP 0.25 TH 0.012
15 16 28 29 41 42 87 88 107 108 127 128 174 175 181 182 202 203 209 -
210 TABLE TB ISMB500 WP 0.25 TH 0.012
54 55 147 148 188 189 216 217 TABLE ST ISMB500
14 17 TO 20 27 30 TO 33 40 43 TO 46 53 56 TO 59 86 89 TO 92 106 109 -
110 TO 112 126 129 TO 132 146 149 TO 152 173 176 TO 180 183 TO 187 -
190 TO 193 201 204 TO 208 211 TO 215 218 TO 221 TABLE ST ISMB500
8 TO 13 74 TO 78 222 227 TABLE ST ISMB300
_LONGBEAM_106 TABLE ST ISMB300
_LONGBEAM_108 TABLE ST ISMB300
47 TO 52 134 TO 138 225 230 TABLE ST ISMB300
73 133 TABLE ST ISMB400
60 TO 65 154 TO 158 226 231 TABLE ST ISMB450
153 TABLE ST ISMB500
_TRBEAM_105 TABLE ST ISMB500
_TRBEAM_107 TABLE ST ISMB500
_TRBEAM_109 TABLE ST ISMB500
_TRBEAM_112 TABLE ST ISMB350
_TRBEAM_113.5 TABLE ST ISMB400
300 TO 314 317 319 TO 327 330 335 340 345 TABLE LD ISA75X75X8 SP 0.01
_HOR_BR TABLE LD ISA75X75X8 SP 0.01
_VER_BR100 UPTABLE 1 STAR11011012
_VER_BR104 UPTABLE 1 STAR10010010
_VER_BR106 UPTABLE 1 STAR10010010
_VER_BR108 UPTABLE 1 STAR10010010
_VER_BR110 UPTABLE 1 STAR10010010
315 316 318 TABLE LD ISA90X90X8 SP 0.01
*----------------------------------------------------------------------------------*
CONSTANTS
BETA 90 MEMB 1 TO 7 14 TO 20 27 TO 33 40 TO 46 53 TO 59 66 TO 72 86 -
87 TO 92 106 TO 112 126 TO 132 146 TO 152 166 TO 221
MATERIAL STEEL ALL
SUPPORTS
1 TO 7 43 TO 49 FIXED BUT MY MZ
*----------------------------------------------------------------------------------*
MEMBER RELEASE
```

```
8 TO 13 21 23 TO 26 34 TO 39 47 TO 52 60 TO 65 73 TO 78 93 TO 98 113 -
114 TO 118 133 TO 138 153 TO 158 228 START MY MZ
8 10 TO 13 21 TO 26 34 36 TO 39 47 49 TO 52 60 62 TO 65 73 75 TO 78 -
93 95 TO 98 113 115 TO 118 133 135 TO 138 153 155 TO 158 222 TO 227 -
229 TO 231 END MY MZ
MEMBER TRUSS
232 TO 271 328 329 331 TO 334 336 TO 339 341 TO 344 346 347
MEMBER TRUSS
_STRUT
***********************************************************************************
LOAD 1 DEAD LOAD - SELF WEIGHT
***********************************************************************************
SELFWEIGHT Y -1
*------------------------SELF WEIGHT OF SECONDARY BEAMS ------------------------------*
MEMBER LOAD
60 TO 65 153 TO 158 CON GY -2.096 2.65
60 62 TO 65 153 155 TO 158 CON GY -2.096 5.35
226 231 CON GY -2.096 1.35
*---------------------SELF WEIGHT OF PORTAL AT LOWER TIERS ---------------------------*
MEMBER LOAD
8 10 TO 13 21 23 TO 26 34 36 TO 39 73 75 TO 78 93 95 TO 98 113 115 -
116 TO 118 CON GY -2.21 4
JOINT LOAD
142 TO 144 147 TO 149 FY -2.21
*---------------------SELF WEIGHT OF PORTAL AT TOP TIERS -----------------------------*
MEMBER LOAD
47 49 TO 52 133 135 TO 138 CON GY -2.652 4
JOINT LOAD
145 150 FY -2.625
***********************************************************************************
LOAD 2 DEAD LOAD - FIREPROOFING
***********************************************************************************
MEMBER LOAD
*----------------------------------FOR COLUMNS---------------------------------------*
_COL_100 UNI GY -2.434
_COL_104 UNI GY -2.434
15 16 28 29 41 42 87 88 107 108 127 128 174 175 181 182 202 203 209 -
210 UNI GY -2.434
54 55 147 148 188 189 216 217 UNI GY -2.29
14 17 TO 20 27 30 TO 33 40 43 TO 46 53 56 TO 59 86 89 TO 92 106 109 -
110 TO 112 126 129 TO 132 146 149 TO 152 173 176 TO 180 183 TO 187 -
190 TO 193 201 204 TO 208 211 TO 215 218 TO 221 UNI GY -2.29
*------------------------------FOR LONG BEAMS----------------------------------------*
_LONGBEAM_104 UNI GY -1.57
_LONGBEAM_106 UNI GY -1.57
_LONGBEAM_108 UNI GY -1.57
_LONGBEAM_110 UNI GY -1.57
60 TO 65 154 TO 158 226 231 UNI GY -1.72
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153 UNI GY -1.95
*------------------------------FOR TRANSVERSE BEAMS-----------------------------------*
_TRBEAM_105 UNI GY -1.95
_TRBEAM_107 UNI GY -1.95
_TRBEAM_109 UNI GY -1.95
_TRBEAM_112 UNI GY -1.45
_TRBEAM_113.5 UNI GY -1.57
*------------------------------FOR VERTICAL BRACE-------------------------------------*
_VER_BR100 UNI GY -1.93
_VER_BR104 UNI GY -1.74
_VER_BR106 UNI GY -1.74
_VER_BR108 UNI GY -1.74
_VER_BR110 UNI GY -1.74
*-----------------------FIREPROOFING LOAD FROM SECONDARY BEAMS -----------------------*
MEMBER LOAD
60 TO 65 153 TO 158 CON GY -5.8 2.65
60 62 TO 65 153 155 TO 158 CON GY -5.8 5.35
226 231 CON GY -5.8 1.35
*----------------FIREPROOFING LOAD FROM PORTAL AT LOWER TIERS ------------------------*
MEMBER LOAD
8 10 TO 13 21 23 TO 26 34 36 TO 39 73 75 TO 78 93 95 TO 98 113 115 -
116 TO 118 CON GY -9.73 4
JOINT LOAD
142 TO 144 147 TO 149 FY -9.73
*----------------FIREPROOFING LOAD FROM PORTAL AT TOP TIERS --------------------------*
MEMBER LOAD
47 49 TO 52 133 135 TO 138 CON GY -11.9 4
JOINT LOAD
145 150 FY -11.9
*************************************************************************************
LOAD 3 DEAD LOAD - WALKWAY & CABLE TRAY
*************************************************************************************
MEMBER LOAD
*-----------------------------------LOAD FROM WALKWAY --------------------------------*
_TRBEAM_113.5 CON GY -3.062 4.225
*--------------- LOAD FROM WALKWAY ELECTRICAL CABLE TRAY MAINTENANCE -----------------*
_TRBEAM_113.5 CON GY -3.062 6.05
*-------------------- LOAD FROM INSTRUMENT CABLE TRAY (FUTURE) -----------------------*
159 TO 162 UNI GY -19.125 0.5 1.7
163 TO 165 UNI GY -18.9 0.6 1.6
*----------------------- LOAD FROM INSTRUMENT CABLE TRAY -----------------------------*
159 TO 162 UNI GY -19.125 1.99 3.19
163 TO 165 UNI GY -18.9 2.09 3.09
*------------------------- LOAD FROM ELECTRICAL CABLE TRAY ---------------------------*
_TRBEAM_113.5 CON GY -8.5 4.675
_TRBEAM_113.5 CON GY -8.5 7.425
*------------------------SELF WEIGHT OF SECONDARY BEAMS ------------------------------*
60 TO 62 CON GY -41.65 2.65
```

60 62 CON GY -41.65 5.35
231 CON GY -41.65 1.35
63 TO 65 CON GY -35.42 2.65
63 TO 65 CON GY -35.42 5.35
153 155 CON GY -27.38 2.65
153 155 CON GY -27.38 5.35
154 CON GY -27.38 2.65
226 CON GY -27.38 1.35
156 TO 158 CON GY -25.51 2.65
156 TO 158 CON GY -25.51 5.35
------------------------------ LOAD FROM STAIRCASE --------------------------------
73 133 CON GY -2.7 0.28
73 133 CON GY -2.7 1.18
73 133 CON GY -2.7 1.42
73 133 CON GY -2.7 2.32
153 CON GY -5.4 2.5
JOINT LOAD
78 FY -5.4
----------------------------- LOAD FROM PSV PLATFORM -------------------------------
39 40 FY -8.5
------------------- JOINT LOAD FROM WALKWAY (CANTILEVERED) -------------------------
36 TO 42 FY -10
****
LOAD 4 LIVE LOAD
****
MEMBER LOAD
----------------------------------LOAD FROM WALKWAY --------------------------------
_TRBEAM_113.5 CON GY -6.075 4.225
--------------- LOAD FROM WALKWAY ELECTRICAL CABLE TRAY MAINTENANCE -----------------
_TRBEAM_113.5 CON GY -6.075 6.05
-----------------------SELF WEIGHT OF SECONDARY BEAMS ------------------------------
60 TO 62 CON GY -4.05 2.65
60 62 CON GY -4.05 5.35
231 CON GY -4.05 1.35
63 TO 65 CON GY -4.05 2.65
63 TO 65 CON GY -4.05 5.35
153 TO 155 CON GY -7.1 2.65
153 155 CON GY -7.1 5.35
226 CON GY -7.1 1.35
156 TO 158 CON GY -7.1 2.65
156 TO 158 CON GY -7.1 5.35
------------------------------ LOAD FROM STAIRCASE --------------------------------
73 133 CON GY -9 0.28
73 133 CON GY -9 1.18
73 133 CON GY -9 1.42
73 133 CON GY -9 2.32
153 CON GY -18 2.5
JOINT LOAD

78 FY -18

------------------------------ LOAD FROM PSV PLATFORM -------------------------------

39 40 FY -40

------------------- JOINT LOAD FROM WALKWAY (CANTILEVERED) -------------------------

36 TO 42 FY -20

****

LOAD 5 PIPING EMPTY LOAD

****

MEMBER LOAD

_TRBEAM_105 UNI GY -10

_TRBEAM_107 UNI GY -10

119 TO 125 UNI GY -8 1.4 4

286 TO 292 UNI GY -8

_TRBEAM_112 UNI GY -10

------------------------- FLARE LINE AT LEVEL 109.00 --------------------------------

119 TO 125 CON GY -16.56 0.91

------------------------------ LOAD FROM PSV PLATFORM -------------------------------

JOINT LOAD

39 40 FY -6

------------------------------- LOAD FROM MONORIAL ----------------------------------

54 FY -28.125

53 FY -9.375

-------------------------- LOAD DUE TO EXPANSION LOOP -------------------------------

70 FY -29

****

LOAD 6 PIPING OPERATING LOAD

****

MEMBER LOAD

_TRBEAM_105 UNI GY -14

_TRBEAM_107 UNI GY -14

119 TO 125 UNI GY -10 1.4 4

286 TO 292 UNI GY -10

_TRBEAM_112 UNI GY -14

------------------------- FLARE LINE AT LEVEL 109.00 --------------------------------

119 TO 125 CON GY -19.52 0.91

------------------------------ LOAD FROM PSV PLATFORM -------------------------------

JOINT LOAD

39 40 FY -6

-------------------------- LOAD DUE TO EXPANSION LOOP -------------------------------

70 FY -29

****

LOAD 7 PIPING TEST LOAD

****

MEMBER LOAD

_TRBEAM_105 UNI GY -16

_TRBEAM_107 UNI GY -16

119 TO 125 UNI GY -14 1.4 4

286 TO 292 UNI GY -14

```
_TRBEAM_112 UNI GY -16
*------------------------ FLARE LINE AT LEVEL 109.00 -------------------------------*
119 TO 125 CON GY -16.56 0.91
*----------------------------- LOAD FROM PSV PLATFORM -------------------------------*
JOINT LOAD
39 40 FY -6
*------------------------- LOAD DUE TO EXPANSION LOOP ------------------------------*
70 FY -29
*********************************************************************************
LOAD 8 FRICTIONAL FORCE - OPERATING CASE
*********************************************************************************
MEMBER LOAD
_TRBEAM_105 UNI GX 1.4
_TRBEAM_107 UNI GX 1.4
119 TO 125 UNI GX 1 1.4 4
286 TO 292 UNI GX 1
119 TO 125 UNI GX 5.856 0.91 4
_TRBEAM_112 UNI GX 1.4
JOINT LOAD
8 TO 14 FZ 11.2
15 TO 21 FZ 11.2
22 TO 28 FZ 6.6
29 TO 35 FZ 11.2
22 TO 28 FX 5.856
*---------------------- MOMENT AT FLARE LINE LOCATION -----------------------------*
MEMBER LOAD
119 TO 125 CMOM GX 5.856 0.91
119 TO 125 CMOM GZ 5.856 0.91
*----------------------------- LOAD FROM PSV PLATFORM -----------------------------*
JOINT LOAD
39 40 FZ 0.6
39 40 FX 0.6
*-----------------------FLOW LINE -----------------------------------------------*
17 TO 21 FZ 4.9
20 21 FZ 1.35
*********************************************************************************
LOAD 9 ANCHOR FORCE
*********************************************************************************
JOINT LOAD
12 19 FZ 15
26 FZ 25
161 168 FX 30
175 FX 40
161 168 MX 15 MY 20 MZ 8
175 MX 18 MY 29.5 MZ 11.5
*-------------------------------- GUIDE FORCES  ----------------------------------*
28 FZ 12
177 FX 13.5
```

```
*------------------------------ THRUST FROM PSV ----------------------------------*
40 FX 2
********************************************************************************
LOAD 10 WIND IN X DIRECTION
********************************************************************************
*------------------------- WIND LOAD ON CABLE TRAY -------------------------------*
JOINT LOAD
36 78 FX 16
*------------------------- WIND LOAD ON PIPE RACK --------------------------------*
86 114 FX 47
93 121 FX 38
100 128 FX 41
107 135 FX 36
36 78 FX 27
1 43 FX 2.9
*------------------------- WIND LOAD ON STAIRCASE --------------------------------*
JOINT LOAD
86 FX 12
93 FX 7.95
100 FX 4.35
107 FX 11.5
78 FX 7.29
********************************************************************************
LOAD 11 WIND IN Z DIRECTION
*********************************************************************************
*------------------------- WIND LOAD ON PIPE RACK --------------------------------*
JOINT LOAD
8 TO 28 FZ 18.6
29 TO 42 FZ 20.5
*------------------------- WIND LOAD ON STAIRCASE --------------------------------*
JOINT LOAD
15 FZ 4.75
36 FZ 3.6
*********************************************************************************
LOAD 12 SEISMIC LOAD IN X DIRECTION
*********************************************************************************
*----------------------------- AT LEVEL 104.00 -----------------------------------*
JOINT LOAD
86 114 FX 5.99
*----------------------------- AT LEVEL 106.00 -----------------------------------*
93 121 FX 12.89
*----------------------------- AT LEVEL 108.00 -----------------------------------*
100 128 FX 21.63
*----------------------------- AT LEVEL 110.00 -----------------------------------*
107 FX 37.08
135 FX 38.08
*----------------------------- AT LEVEL 113.50 -----------------------------------*
36 FX 103.72
```

```
78 FX 69.64
************************************************************************************
LOAD 13 SEISMIC LOAD IN Z DIRECTION
************************************************************************************
JOINT LOAD
*----------------------------- AT LEVEL 105.00 ------------------------------------*
8 14 FZ 1.8
9 10 FZ 1.85
11 TO 13 FZ 1.92
*----------------------------- AT LEVEL 107.00 ------------------------------------*
15 21 FZ 3.07
16 17 FZ 3.41
18 TO 20 FZ 3.62
*----------------------------- AT LEVEL 109.00 ------------------------------------*
22 FZ 5.51
28 FZ 5.15
23 24 FZ 4.84
25 TO 27 FZ 5.17
*----------------------------- AT LEVEL 112.00 ------------------------------------*
29 FZ 10.19
35 FZ 9.35
30 31 FZ 10.53
32 TO 34 FZ 11.71
*----------------------------- AT LEVEL 113.50 ------------------------------------*
36 FZ 15.18
42 FZ 12.99
37 38 FZ 15.66
39 TO 41 FZ 20.91
************************************************************************************
*LOAD COMBINATIONS
************************************************************************************
*----------------------------- EMPTY CONDITION ------------------------------------*
LOAD COMB 51 (SW+FP+DL+LL+P(E))
1 1.0 2 1.0 3 1.0 4 1.0 5 1.0
LOAD COMB 52 (SW+FP+DL+LL+P(E)+WZ)
1 1.0 2 1.0 3 1.0 4 1.0 5 1.0 11 1.0
LOAD COMB 53 (SW+FP+DL+LL+P(E)+WX)
1 1.0 2 1.0 3 1.0 4 1.0 5 1.0 10 1.0
LOAD COMB 54 (SW+FP+DL+LL+P(E)-WZ)
1 1.0 2 1.0 3 1.0 4 1.0 5 1.0 11 -1.0
LOAD COMB 55 (SW+FP+DL+LL+P(E)-WX)
1 1.0 2 1.0 3 1.0 4 1.0 5 1.0 10 -1.0
*----------------------------- TEST CONDITION ------------------------------------*
LOAD COMB 81 (SW+FP+DL+LL+P(T))
1 1.0 2 1.0 3 1.0 4 1.0 7 1.0
LOAD COMB 82 (SW+FP+DL+LL+P(T)+ 25%WZ)
1 1.0 2 1.0 3 1.0 4 1.0 7 1.0 11 0.25
LOAD COMB 83 (SW+FP+DL+LL+P(T)+ 25%WX)
```

```
1 1.0 2 1.0 3 1.0 4 1.0 7 1.0 10 0.25
LOAD COMB 84 (SW+FP+DL+LL+P(T)- 25%WZ)
1 1.0 2 1.0 3 1.0 4 1.0 7 1.0 11 -0.25
LOAD COMB 85 (SW+FP+DL+LL+P(T)- 25%WX)
1 1.0 2 1.0 3 1.0 4 1.0 7 1.0 10 -0.25
*------------------------ OPERATING CONDITION ------------------------------------*
*---------------- FOR COLUMN DESIGN AND SUPPORT REACTION --------------------------*
LOAD COMB 101 (SW+FP+DL+LL+P(O)+FF+AF)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 1.0 9 1.0
LOAD COMB 102 (SW+FP+DL+LL+P(O)+FF+AF+WZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 1.0 9 1.0 11 1.0
LOAD COMB 103 (SW+FP+DL+LL+P(O)+FF+AF+WX)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 1.0 9 1.0 10 1.0
LOAD COMB 104 (SW+FP+DL+LL+P(O)-FF-AF-WZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 -1.0 9 -1.0 11 -1.0
LOAD COMB 105 (SW+FP+DL+LL+P(O)-FF-AF-WX)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 -1.0 9 -1.0 10 -1.0
LOAD COMB 106 (SW+FP+DL+LL+P(O)+FF+AF+VZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 1.0 9 1.0 13 1.0
LOAD COMB 107 (SW+FP+DL+LL+P(O)+FF+AF+VX)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 1.0 9 1.0 12 1.0
LOAD COMB 108 (SW+FP+DL+LL+P(O)-FF-AF-VZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 -1.0 9 -1.0 13 -1.0
LOAD COMB 109 (SW+FP+DL+LL+P(O)-FF-AF-VX)
1 1.0 2 1.0 3 1.0 4 1.0 6 1.0 8 -1.0 9 -1.0 12 -1.0
*---------------- COMBINATIONS FOR TRANSVERSE BEAM DESIGN ------------------------*
*------------- 10% REDUCTION OF PIPING LOAD ON TRANSVERSE BEAMS -----------------*
LOAD COMB 110 (SW+FP+DL+LL+0.9P(O)+0.9FF+AF+WZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 0.9 9 1.0 11 1.0
LOAD COMB 111 (SW+FP+DL+LL+0.9P(O)+0.9FF+AF+WX)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 0.9 9 1.0 10 1.0
LOAD COMB 112 (SW+FP+DL+LL+0.9P(O)-0.9FF-AF-WZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 -0.9 9 -1.0 11 -1.0
LOAD COMB 113 (SW+FP+DL+LL+0.9P(O)-0.9FF-AF-WX)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 -0.9 9 -1.0 10 -1.0
LOAD COMB 114 (SW+FP+DL+LL+0.9P(O)+0.9FF+AF+VZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 0.9 9 1.0 13 1.0
LOAD COMB 115 (SW+FP+DL+LL+0.9P(O)+0.9FF+AF+VX)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 0.9 9 1.0 12 1.0
LOAD COMB 116 (SW+FP+DL+LL+0.9P(O)-0.9FF-AF-VZ)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 -0.9 9 -1.0 13 -1.0
LOAD COMB 117 (SW+FP+DL+LL+0.9P(O)-0.9FF-AF-VX)
1 1.0 2 1.0 3 1.0 4 1.0 6 0.9 8 -0.9 9 -1.0 12 -1.0
*------------------------------------------------------------------------------*
PERFORM ANALYSIS
*----------------------------- STEEL DESIGN -----------------------------------*
PARAMETER
CODE INDIAN
```

```
*----------------- EFFECTIVE LENGTH FOR TRANSVERSE BEAMS -------------------------*
LY 4 MEMB _TRBEAM_105
LZ 8 MEMB _TRBEAM_105
UNL 4 MEMB _TRBEAM_105
LY 4 MEMB _TRBEAM_107
LZ 8 MEMB _TRBEAM_107
UNL 4 MEMB _TRBEAM_107
LY 4 MEMB _TRBEAM_109
LZ 8 MEMB _TRBEAM_109
UNL 4 MEMB _TRBEAM_109
LY 4 MEMB _TRBEAM_112
LZ 8 MEMB _TRBEAM_112
UNL 4 MEMB _TRBEAM_112
LY 3.8 MEMB _TRBEAM_113.5
LZ 8 MEMB _TRBEAM_113.5
UNL 3.8 MEMB _TRBEAM_113.5
*--------------------- EFFECTIVE LENGTH FOR LONG. BEAMS --------------------------*
LY 4 MEMB _LONGBEAM_104
LZ 8 MEMB _LONGBEAM_104
UNL 4 MEMB _LONGBEAM_104
LY 4 MEMB _LONGBEAM_106
LZ 8 MEMB _LONGBEAM_106
UNL 4 MEMB _LONGBEAM_106
LY 4 MEMB _LONGBEAM_108
LZ 8 MEMB _LONGBEAM_108
UNL 4 MEMB _LONGBEAM_108
LY 4 MEMB _LONGBEAM_110
LZ 8 MEMB _LONGBEAM_110
UNL 4 MEMB _LONGBEAM_110
LY 2.65 MEMB _LONGBEAM_113.5
LZ 8 MEMB _LONGBEAM_113.5
UNL 2.65 MEMB _LONGBEAM_113.5
*---------------------- EFFECTIVE LENGTH FOR COLUMN ------------------------------*
LY 3.7 MEMB _COL_104-105
LZ 4.7 MEMB _COL_104-105
UNL 3.7 MEMB _COL_104-105
LY 1 MEMB 14 TO 20 27 TO 33 86 TO 92 106 TO 112 173 TO 186 201 TO 214
LZ 2 MEMB 14 TO 20 27 TO 33 86 TO 92 106 TO 112 173 TO 186 201 TO 214
UNL 1 MEMB 14 TO 20 27 TO 33 86 TO 92 106 TO 112 173 TO 186 201 TO 214
LY 2 MEMB 40 TO 46 126 TO 132 187 TO 193 215 TO 221
LZ 3 MEMB 40 TO 46 126 TO 132 187 TO 193 215 TO 221
UNL 2 MEMB 40 TO 46 126 TO 132 187 TO 193 215 TO 221
LY 3.5 MEMB 53 TO 59 146 TO 152
LZ 1.5 MEMB 53 TO 59 146 TO 152
UNL 1.5 MEMB 53 TO 59 146 TO 152
MAIN 250 MEMB _HOR_BR
LY 4 MEMB _STRUT
LZ 4 MEMB _STRUT
```

```
UNL 4 MEMB _STRUT
MAIN 250 MEMB _STRUT
*---------------------------- LONG TERM CASE -------------------------------------*
LOAD LIST 101
PARAMETER
CODE INDIAN
TRACK 2 ALL
RATIO 1 ALL
BEAM 1 ALL
CHECK CODE ALL
*---------------------------- SHORT TERM CASE -------------------------------------*
*------------------------- FOR TRANSVERSE BEAM DESIGN -----------------------------*
LOAD LIST 110 TO 117
PARAMETER
CODE INDIAN
RATIO 1.33 ALL
BEAM 1 ALL
CHECK CODE MEMB _TRBEAM_105
CHECK CODE MEMB _TRBEAM_107
CHECK CODE MEMB _TRBEAM_109
CHECK CODE MEMB _TRBEAM_112
CHECK CODE MEMB _TRBEAM_113.5
*---------- FOR COLUMN, LONG BEAM AT TOP, ELEVATION-PLAN BRACING, STRUT -----------*
LOAD LIST 101 TO 109
PARAMETER
CODE INDIAN
RATIO 1.33 ALL
BEAM 1 ALL
CHECK CODE MEMB _COL_104-105
CHECK CODE MEMB _COL_106
CHECK CODE MEMB _COL_107
CHECK CODE MEMB _COL_108
CHECK CODE MEMB _COL_109
CHECK CODE MEMB _COL_110
CHECK CODE MEMB _COL_112
CHECK CODE MEMB _LONGBEAM_104
CHECK CODE MEMB _LONGBEAM_106
CHECK CODE MEMB _LONGBEAM_108
CHECK CODE MEMB _LONGBEAM_110
CHECK CODE MEMB _LONGBEAM_113.5
CHECK CODE MEMB _STRUT
CHECK CODE MEMB _HOR_BR
CHECK CODE MEMB _VER_BR100
CHECK CODE MEMB _VER_BR104
CHECK CODE MEMB _VER_BR106
CHECK CODE MEMB _VER_BR108
CHECK CODE MEMB _VER_BR110
FINISH
```

C.1 GENERAL

This section discuses design of secondary portal, which is not model with pipe rack only loads from secondary portal has transferred to pipe rack in from of point loads.

C.2 STAAD INPUT FILE

```
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 05-Dec-06
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0 1 0; 3 8 1 0; 4 8 0 0; 5 4 1 0;
MEMBER INCIDENCES
1 1 2; 2 2 5; 3 3 4; 4 5 3;
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.05e+008
POISSON 0.3
DENSITY 78.5
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
MEMBER PROPERTY INDIAN
1 TO 4 TABLE ST ISMB300
CONSTANTS
MATERIAL STEEL MEMB 1 TO 4
SUPPORTS
1 4 FIXED BUT MZ
5 FIXED BUT FX FY MX MY MZ
*-------------------- LOAD 1 DEAD LOAD- SELFWEIGNT ------------------*
LOAD 1 DEAD LOAD
SELFWEIGHT Y -1
*-------------------- LOAD 2 DEAD LOAD - FIREPROOFING --------------*
LOAD 2 FIREPROOFING LOAD
MEMBER LOAD
2 4 UNI GY -1.89 0 4
1 3 UNI GY -2.17 0 1
*-------------------- LOAD 3 PIPE LOAD 200 KG/SQM ------------------*
LOAD 3 PIPE LOAD 200 KG/SQM
MEMBER LOAD
2 4 UNI GY -4 0 4
*-------------------- LOAD 4 FRICTIONAL FORCE ----------------------*
LOAD 4 FRICTIONAL FORCE
MEMBER LOAD
2 4 UNI GZ 0.4 0 4
JOINT LOAD
2 3 FX 1.6
*---------------------- LOAD COMBINATIONS --------------------------*
```

```
LOAD COMB 10 DL + FP + PIPE(200) + FRICTIONAL FORCE
1 1 2 1 3 1 4 1
LOAD COMB 20 DL + PIPE(200) + FRICTIONAL FORCE
1 1 3 1 4 1
PERFORM ANALYSIS
LOAD LIST 10 20
PARAMETER
CODE INDIA
UNIT MMS NEWTON
FYLD 250 ALL
MAIN 0 MEMB 1 TO 4
BEAM 1 ALL
UNIT METER KNS
LY 4 MEMB 2 4
LZ 8 MEMB 2 4
LY 2 MEMB 1 3
LZ 1 MEMB 1 3
UNL 4 MEMB 2 4
UNL 2 MEMB 1 3
CHECK CODE ALL
FINISH
```

C.2 LOADING DIAGRAM

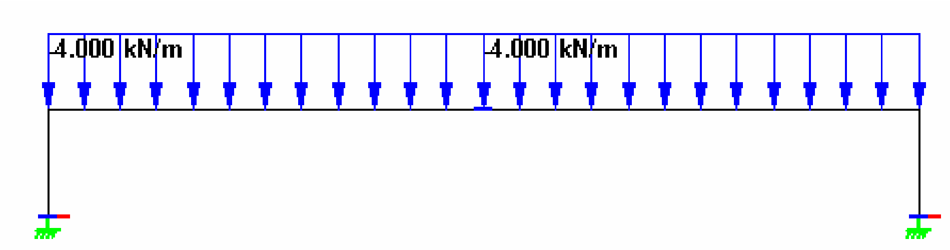


FIG C.1 PIPE LOAD

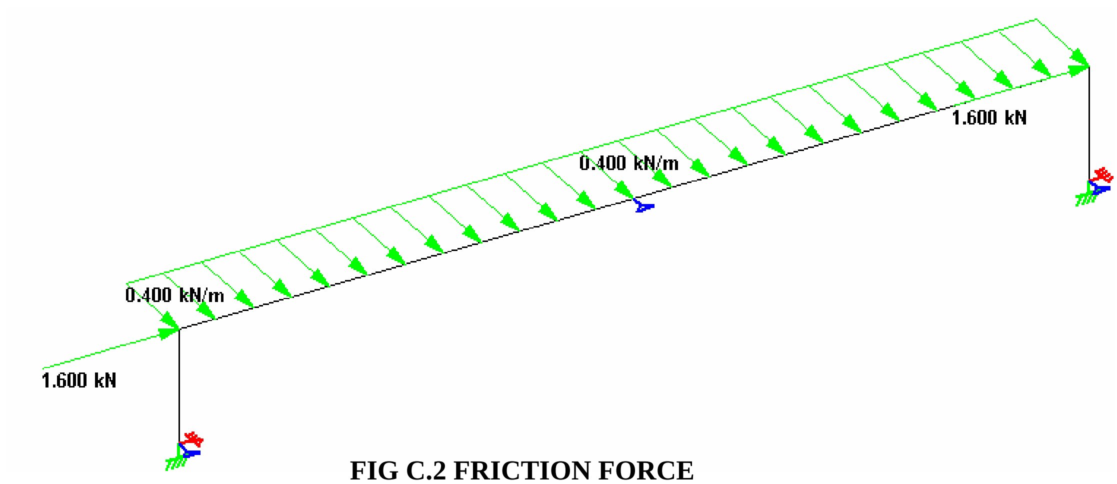


FIG C.2 FRICTION FORCE

C.3 BENDING MOMENT DIAGRAM

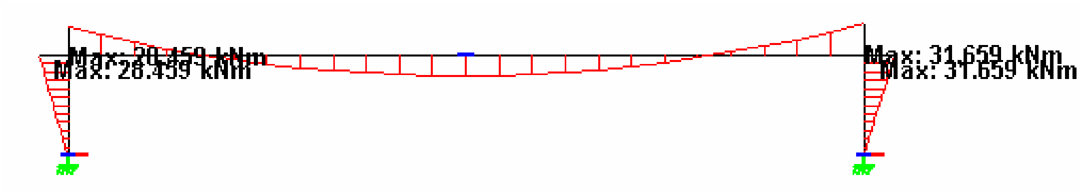


FIG C.3 B.M DIAGRAM FOR DL + FP + PIPE (200) + FRICTIONAL FORCE

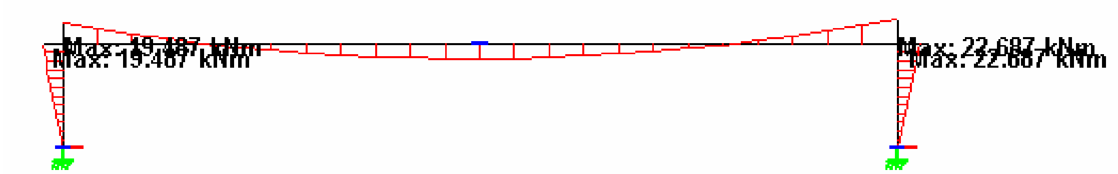


FIG C.3 B.M DIAGRAM FOR DL + PIPE (200) + FRICTIONAL FORCE

C.4 STAAD DESIGN OUTPUT

ALL UNITS ARE - KNS METE

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
1	ST ISMB300	PASS	IS-7.1.1(A)	0.397	10
		24.93 C	0.00	28.46	1.00
2	ST ISMB300	PASS	IS-7.1.1(A)	0.636	10
		30.06 C	0.01	28.46	0.00
3	ST ISMB300	PASS	IS-7.1.1(A)	0.438	10
		25.73 C	0.00	31.66	0.00
4	ST ISMB300	PASS	IS-7.1.1(A)	0.695	10
		30.06 C	0.01	31.66	4.00

APPENDIX D STAAD DESIGN OUTPUT

D.1 DESIGN RESULTS FOR LONG TERM CASE

ALL UNITS ARE IN KN METER (UNLESS OTHERWISE NOTED)

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
1	TB ISMB500	PASS	482.76 C	-52.84	IS-7.1.1(A)	0.362
2	TB ISMB500	PASS	474.56 C	-53.26	IS-7.1.1(A)	0.358
3	TB ISMB500	PASS	795.57 C	-64.40	IS-7.1.1(A)	0.553
4	TB ISMB500	PASS	646.10 C	-80.24	IS-7.1.1(A)	0.503
5	TB ISMB500	PASS	618.77 C	-101.41	IS-7.1.1(A)	0.530
6	TB ISMB500	PASS	577.05 C	-91.02	IS-7.1.1(A)	0.487
7	TB ISMB500	PASS	458.46 C	-90.29	IS-7.1.1(A)	0.422
8	ST ISMB300	PASS	2.28 C	-39.98	IS-7.1.1(A)	0.750
9	ST ISMB300	PASS	125.00 C	5.64	IS-7.1.1(A)	0.539
10	ST ISMB300	PASS	6.70 T	-39.98	IS-7.1.2	0.430
11	ST ISMB300	PASS	5.94 T	-39.98	IS-7.1.2	0.429
12	ST ISMB300	PASS	3.61 T	-39.98	IS-7.1.2	0.427
13	ST ISMB300	PASS	1.30 T	-39.98	IS-7.1.2	0.424
14	ST ISMB500	PASS	391.66 C	36.57	IS-7.1.1(B)	0.378
15	TB ISMB500	PASS	429.04 C	49.49	IS-7.1.1(B)	0.419
16	TB ISMB500	PASS	613.20 C	41.92	IS-7.1.1(B)	0.420
17	ST ISMB500	PASS	541.46 C	13.77	IS-7.1.1(B)	0.449
18	ST ISMB500	PASS	521.94 C	34.83	IS-7.1.1(B)	0.524
19	ST ISMB500	PASS	476.93 C	32.57	IS-7.1.1(B)	0.428
20	ST ISMB500	PASS	372.79 C	30.35	IS-7.1.1(B)	0.339
21	ST ISMB300	PASS	0.47 C	-39.98	IS-7.1.1(A)	0.744
22	ST ISMB300	PASS	106.72 C	2.87	IS-7.1.1(A)	0.426
23	ST ISMB300	PASS	9.18 T	-39.98	IS-7.1.2	0.433
24	ST ISMB300	PASS	1.84 T	-39.98	IS-7.1.2	0.425
25	ST ISMB300	PASS	1.75 T	-39.98	IS-7.1.2	0.425
26	ST ISMB300	PASS	PASS	-39.98	IS-7.1.2	0.427
27	ST ISMB500	PASS	310.57 C	36.06	IS-7.1.1(B)	0.320
28	TB ISMB500	PASS	377.86 C	11.65	IS-7.1.1(A)	0.307
29	TB ISMB500	PASS	445.74 C	15.68	IS-7.1.1(B)	0.326
30	ST ISMB500	PASS	450.83 C	41.23	IS-7.1.1(B)	0.558
31	ST ISMB500	PASS	432.77 C	28.47	IS-7.1.1(B)	0.428
32	ST ISMB500	PASS	383.82 C	42.19	IS-7.1.1(B)	0.453
33	ST ISMB500	PASS	295.28 C	34.87	IS-7.1.1(B)	0.331
34	ST ISMB300	PASS	10.69 C	-39.98	IS-7.1.1(A)	0.780
35	ST ISMB300	PASS	71.80 C	-2.82	IS-7.1.1(A)	0.301
36	ST ISMB300	PASS	41.58 T	-39.98	IS-7.1.2	0.472
37	ST ISMB300	PASS	25.29 T	-39.98	IS-7.1.2	0.452
38	ST ISMB300	PASS	16.68 T	-39.98	IS-7.1.2	0.442
39	ST ISMB300	PASS	10.65 T	-39.98	IS-7.1.2	0.435
40	ST ISMB500	PASS	239.68 C	29.79	IS-7.1.1(A)	0.332

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
41	TB ISMB500	PASS	311.36 C	36.40	IS-7.1.1(A)	0.495
42	TB ISMB500	PASS	326.84 C	32.95	IS-7.1.1(A)	0.447
43	ST ISMB500	PASS	366.51 C	30.46	IS-7.1.1(A)	0.416
44	ST ISMB500	PASS	353.44 C	33.43	IS-7.1.1(A)	0.431
45	ST ISMB500	PASS	299.57 C	31.79	IS-7.1.1(A)	0.420
46	ST ISMB500	PASS	226.47 C	33.05	IS-7.1.1(B)	0.354
47	ST ISMB300	PASS	5.02 C	-45.20	IS-7.1.1(A)	0.857
48	ST ISMB300	PASS	10.99 T	-3.07	IS-7.1.2	0.045
49	ST ISMB300	PASS	16.85 T	-45.20	IS-7.1.2	0.498
50	ST ISMB300	PASS	12.64 T	-45.20	IS-7.1.2	0.493
51	ST ISMB300	PASS	12.07 T	-45.20	IS-7.1.2	0.492
52	ST ISMB300	PASS	5.70 T	-45.20	IS-7.1.2	0.484
53	ST ISMB500	PASS	147.60 C	-60.59	IS-7.1.1(A)	0.347
54	ST ISMB500	PASS	167.17 C	38.10	IS-7.1.1(A)	0.642
55	ST ISMB500	PASS	166.97 C	38.43	IS-7.1.1(A)	0.589
56	ST ISMB500	PASS	258.96 C	-59.45	IS-7.1.1(A)	0.468
57	ST ISMB500	PASS	250.73 C	40.34	IS-7.1.1(A)	0.462
58	ST ISMB500	PASS	196.57 C	39.85	IS-7.1.1(A)	0.383
59	ST ISMB500	PASS	139.29 C	39.85	IS-7.1.1(A)	0.320
60	ST ISMB450	PASS	0.77 C	-161.59	IS-7.1.1(A)	0.956
61	ST ISMB450	PASS	1.09 C	34.74	IS-7.1.1(A)	0.207
62	ST ISMB450	PASS	6.58 T	-161.59	IS-7.1.2	0.730
63	ST ISMB450	PASS	5.09 T	-145.08	IS-7.1.2	0.655
64	ST ISMB450	PASS	1.51 T	-145.08	IS-7.1.2	0.652
65	ST ISMB450	PASS	0.78 T	-145.08	IS-7.1.2	0.652
66	TB ISMB500	PASS	596.22 C	-88.17	IS-7.1.1(A)	0.492
67	TB ISMB500	PASS	513.51 C	-81.98	IS-7.1.1(A)	0.435
68	TB ISMB500	PASS	752.08 C	-97.65	IS-7.1.1(A)	0.595
69	TB ISMB500	PASS	593.11 C	-116.23	IS-7.1.1(A)	0.545
70	TB ISMB500	PASS	604.09 C	-136.51	IS-7.1.1(A)	0.591
71	TB ISMB500	PASS	591.31 C	-126.69	IS-7.1.1(A)	0.565
72	TB ISMB500	PASS	513.21 C	-125.62	IS-7.1.1(A)	0.520
73	ST ISMB400	PASS	1.81 C	-72.39	IS-7.1.1(A)	0.772
74	ST ISMB300	PASS	98.19 C	5.63	IS-7.1.1(A)	0.442
75	ST ISMB300	PASS	9.57 T	-39.98	IS-7.1.2	0.434
76	ST ISMB300	PASS	7.17 T	-39.98	IS-7.1.2	0.431
77	ST ISMB300	PASS	2.66 T	-39.98	IS-7.1.2	0.426
78	ST ISMB300	PASS	2.00 T	-39.98	IS-7.1.2	0.425
79	ST ISMB500	PASS	26.03 T	-52.70	IS-7.1.2	0.282
80	ST ISMB500	PASS	9.05 T	-52.05	IS-7.1.2	0.292
81	ST ISMB500	PASS	41.17 T	-52.18	IS-7.1.2	0.303
82	ST ISMB500	PASS	25.12 T	-53.59	IS-7.1.2	0.264
83	ST ISMB500	PASS	18.46 T	-46.07	IS-7.1.2	0.615
84	ST ISMB500	PASS	25.95 T	-53.57	IS-7.1.2	0.275
85	ST ISMB500	PASS	26.09 T	-53.50	IS-7.1.2	0.275
86	ST ISMB500	PASS	446.39 C	-51.96	IS-7.1.1(B)	0.462
87	TB ISMB500	PASS	430.04 C	-54.39	IS-7.1.1(B)	0.419
88	TB ISMB500	PASS	560.58 C	-56.39	IS-7.1.1(B)	0.421

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
89	ST ISMB500	PASS	464.80 C	-54.53	IS-7.1.1(B)	0.493
90	ST ISMB500	PASS	471.12 C	-54.12	IS-7.1.1(B)	0.508
91	ST ISMB500	PASS	461.64 C	-56.41	IS-7.1.1(B)	0.488
92	ST ISMB500	PASS	397.84 C	-58.18	IS-7.1.1(B)	0.445
93	ST ISMB300	PASS	2.05 C	-39.98	IS-7.1.1(A)	0.750
94	ST ISMB300	PASS	75.28 C	2.80	IS-7.1.1(A)	0.313
95	ST ISMB300	PASS	24.71 T	-39.98	IS-7.1.2	0.452
96	ST ISMB300	PASS	24.83 T	-39.98	IS-7.1.2	0.452
97	ST ISMB300	PASS	15.72 T	-39.98	IS-7.1.2	0.441
98	ST ISMB300	PASS	4.53 T	-39.98	IS-7.1.2	0.428
99	ST ISMB500	PASS	10.94 C	-52.05	IS-7.1.1(A)	0.391
100	ST ISMB500	PASS	30.71 C	59.76	IS-7.1.1(A)	0.457
101	ST ISMB500	PASS	14.74 C	-50.06	IS-7.1.1(A)	0.422
102	ST ISMB500	PASS	20.37 C	-52.04	IS-7.1.1(A)	0.413
103	ST ISMB500	PASS	23.41 C	-44.59	IS-7.1.1(A)	0.773
104	ST ISMB500	PASS	12.30 C	-52.04	IS-7.1.1(A)	0.403
105	ST ISMB500	PASS	11.13 C	-51.72	IS-7.1.1(A)	0.399
106	ST ISMB500	PASS	351.54 C	-48.45	IS-7.1.1(B)	0.418
107	TB ISMB500	PASS	349.81 C	-3.49	IS-7.1.1(A)	0.263
108	TB ISMB500	PASS	395.69 C	-53.61	IS-7.1.1(B)	0.287
109	ST ISMB500	PASS	352.59 C	-45.42	IS-7.1.1(B)	0.370
110	ST ISMB500	PASS	354.30 C	-56.51	IS-7.1.1(B)	0.508
111	ST ISMB500	PASS	348.76 C	-42.67	IS-7.1.1(B)	0.620
112	ST ISMB500	PASS	298.75 C	-48.64	IS-7.1.1(B)	0.464
113	ST ISMB300	PASS	0.94 C	-39.98	IS-7.1.1(A)	0.746
114	ST ISMB300	PASS	43.88 C	-2.90	IS-7.1.1(A)	0.202
115	ST ISMB300	PASS	23.99 T	-39.98	IS-7.1.2	0.451
116	ST ISMB300	PASS	24.90 T	-39.98	IS-7.1.2	0.452
117	ST ISMB300	PASS	14.07 T	-39.98	IS-7.1.2	0.439
118	ST ISMB300	PASS	3.91 T	-39.98	IS-7.1.2	0.427
119	ST ISMB500	PASS	12.27 C	-32.79	IS-7.1.1(A)	0.524
120	ST ISMB500	PASS	54.55 C	53.12	IS-7.1.1(A)	0.531
121	ST ISMB500	PASS	22.33 T	-33.41	IS-7.1.2	0.406
122	ST ISMB500	PASS	13.15 C	-34.56	IS-7.1.1(A)	0.555
123	ST ISMB500	PASS	24.67 C	-31.91	IS-7.1.1(A)	0.953
124	ST ISMB500	PASS	12.65 C	-34.67	IS-7.1.1(A)	0.583
125	ST ISMB500	PASS	17.87 C	-36.32	IS-7.1.1(A)	0.605
126	ST ISMB500	PASS	272.97 C	-45.62	IS-7.1.1(A)	0.355
127	TB ISMB500	PASS	270.33 C	-53.64	IS-7.1.1(A)	0.494
128	TB ISMB500	PASS	267.81 C	-45.50	IS-7.1.1(A)	0.429
129	ST ISMB500	PASS	258.56 C	-44.94	IS-7.1.1(A)	0.331
130	ST ISMB500	PASS	255.43 C	-43.06	IS-7.1.1(B)	0.405
131	ST ISMB500	PASS	254.80 C	-43.74	IS-7.1.1(A)	0.362
132	ST ISMB500	PASS	189.11 C	-42.81	IS-7.1.1(A)	0.311
133	ST ISMB400	PASS	1.57 C	-77.01	IS-7.1.1(A)	0.821
134	ST ISMB300	PASS	6.72 T	-3.06	IS-7.1.2	0.040
135	ST ISMB300	PASS	4.03 T	-45.20	IS-7.1.2	0.482
136	ST ISMB300	PASS	2.01 T	-45.20	IS-7.1.2	0.480

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
137	ST ISMB300	PASS	2.38 T	-45.20	IS-7.1.2	0.480
138	ST ISMB300	PASS	1.74 T	-45.20	IS-7.1.2	0.480
139	ST ISMB350	PASS	30.96 T	76.63	IS-7.1.2	0.632
140	ST ISMB350	PASS	16.43 T	77.39	IS-7.1.2	0.623
141	ST ISMB350	PASS	41.24 T	76.29	IS-7.1.2	0.640
142	ST ISMB350	PASS	31.06 T	76.44	IS-7.1.2	0.630
143	ST ISMB350	PASS	27.71 T	76.06	IS-7.1.2	0.628
144	ST ISMB350	PASS	28.27 T	77.21	IS-7.1.2	0.633
145	ST ISMB350	PASS	27.91 T	75.98	IS-7.1.2	0.623
146	ST ISMB500	PASS	137.58 C	64.73	IS-7.1.1(A)	0.348
147	ST ISMB500	PASS	122.79 C	-34.18	IS-7.1.1(A)	0.606
148	ST ISMB500	PASS	114.19 C	-33.01	IS-7.1.1(A)	0.535
149	ST ISMB500	PASS	147.16 C	65.85	IS-7.1.1(A)	0.362
150	ST ISMB500	PASS	143.93 C	63.02	IS-7.1.1(A)	0.350
151	ST ISMB500	PASS	143.59 C	61.68	IS-7.1.1(A)	0.346
152	ST ISMB500	PASS	93.44 C	62.23	IS-7.1.1(A)	0.325
153	ST ISMB500	PASS	1.08 C	-171.34	IS-7.1.1(A)	0.709
154	ST ISMB450	PASS	1.39 C	28.04	IS-7.1.1(A)	0.167
155	ST ISMB450	PASS	4.39 T	-131.85	IS-7.1.2	0.595
156	ST ISMB450	PASS	3.32 T	-126.90	IS-7.1.2	0.572
157	ST ISMB450	PASS	2.23 T	-126.90	IS-7.1.2	0.571
158	ST ISMB450	PASS	1.07 T	-126.90	IS-7.1.2	0.570
159	ST ISMB400	PASS	65.22 C	64.73	IS-7.1.1(A)	0.732
160	ST ISMB400	PASS	60.57 C	64.95	IS-7.1.1(A)	0.811
161	ST ISMB400	PASS	59.98 C	65.29	IS-7.1.1(A)	0.813
162	ST ISMB400	PASS	65.74 C	65.85	IS-7.1.1(A)	0.743
163	ST ISMB400	PASS	62.56 C	63.02	IS-7.1.1(A)	0.798
164	ST ISMB400	PASS	62.52 C	61.68	IS-7.1.1(A)	0.784
165	ST ISMB400	PASS	62.17 C	62.23	IS-7.1.1(A)	0.789
166	TB ISMB500	PASS	523.44 C	69.01	IS-7.1.1(A)	0.422
167	TB ISMB500	PASS	506.89 C	64.38	IS-7.1.1(A)	0.542
168	TB ISMB500	PASS	639.77 C	71.63	IS-7.1.1(A)	0.579
169	TB ISMB500	PASS	546.21 C	82.94	IS-7.1.1(A)	0.466
170	TB ISMB500	PASS	557.19 C	94.51	IS-7.1.1(A)	0.533
171	TB ISMB500	PASS	544.41 C	86.61	IS-7.1.1(A)	0.468
172	TB ISMB500	PASS	480.32 C	84.50	IS-7.1.1(A)	0.425
173	ST ISMB500	PASS	426.05 C	62.98	IS-7.1.1(B)	0.512
174	TB ISMB500	PASS	428.41 C	66.88	IS-7.1.1(B)	0.319
175	TB ISMB500	PASS	472.99 C	66.91	IS-7.1.1(B)	0.343
176	ST ISMB500	PASS	430.45 C	75.37	IS-7.1.1(B)	0.520
177	ST ISMB500	PASS	436.77 C	75.20	IS-7.1.1(B)	0.781
178	ST ISMB500	PASS	427.28 C	80.81	IS-7.1.1(B)	0.797
179	ST ISMB500	PASS	377.50 C	78.05	IS-7.1.1(B)	0.612
180	ST ISMB500	PASS	331.21 C	44.61	IS-7.1.1(B)	0.364
181	TB ISMB500	PASS	329.23 C	37.97	IS-7.1.1(A)	0.489
182	TB ISMB500	PASS	328.26 C	52.79	IS-7.1.1(A)	0.469
183	ST ISMB500	PASS	318.24 C	50.24	IS-7.1.1(B)	0.390
184	ST ISMB500	PASS	319.95 C	62.54	IS-7.1.1(B)	0.572

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
185	ST ISMB500	PASS	314.40 C	51.14	IS-7.1.1(B)	0.379
186	ST ISMB500	PASS	278.42 C	55.62	IS-7.1.1(B)	0.370
187	ST ISMB500	PASS	208.27 C	57.17	IS-7.1.1(B)	0.404
188	ST ISMB500	PASS	189.38 C	56.46	IS-7.1.1(A)	0.696
189	ST ISMB500	PASS	180.97 C	58.11	IS-7.1.1(A)	0.639
190	ST ISMB500	PASS	218.43 C	59.09	IS-7.1.1(B)	0.417
191	ST ISMB500	PASS	215.30 C	61.49	IS-7.1.1(B)	0.425
192	ST ISMB500	PASS	214.68 C	59.01	IS-7.1.1(B)	0.419
193	ST ISMB500	PASS	164.31 C	59.96	IS-7.1.1(A)	0.407
194	TB ISMB500	PASS	453.65 C	-17.78	IS-7.1.1(A)	0.302
195	TB ISMB500	PASS	488.83 C	-1.02	IS-7.1.1(A)	0.417
196	TB ISMB500	PASS	670.64 C	0.92	IS-7.1.1(A)	0.464
197	TB ISMB500	PASS	602.97 C	-13.47	IS-7.1.1(A)	0.361
198	TB ISMB500	PASS	571.86 C	15.78	IS-7.1.1(A)	0.366
199	TB ISMB500	PASS	533.92 C	-11.99	IS-7.1.1(A)	0.330
200	TB ISMB500	PASS	429.34 C	-12.88	IS-7.1.1(A)	0.269
201	ST ISMB500	PASS	371.33 C	-20.37	IS-7.1.1(B)	0.303
202	TB ISMB500	PASS	447.22 C	14.88	IS-7.1.1(B)	0.269
203	TB ISMB500	PASS	513.29 C	18.48	IS-7.1.1(B)	0.286
204	ST ISMB500	PASS	510.26 C	-5.86	IS-7.1.1(B)	0.473
205	ST ISMB500	PASS	487.59 C	-7.61	IS-7.1.1(B)	0.409
206	ST ISMB500	PASS	442.58 C	-2.22	IS-7.1.1(B)	0.351
207	ST ISMB500	PASS	355.61 C	12.41	IS-7.1.1(B)	0.303
208	ST ISMB500	PASS	290.23 C	-21.41	IS-7.1.1(B)	0.525
209	TB ISMB500	PASS	362.70 C	-16.72	IS-7.1.1(A)	0.556
210	TB ISMB500	PASS	376.77 C	-15.01	IS-7.1.1(A)	0.511
211	ST ISMB500	PASS	416.48 C	-17.62	IS-7.1.1(B)	0.576
212	ST ISMB500	PASS	398.42 C	-3.78	IS-7.1.1(B)	0.614
213	ST ISMB500	PASS	349.46 C	-16.02	IS-7.1.1(B)	0.584
214	ST ISMB500	PASS	274.94 C	-9.79	IS-7.1.1(B)	0.500
215	ST ISMB500	PASS	214.88 C	-39.39	IS-7.1.1(B)	0.323
216	ST ISMB500	PASS	230.45 C	-39.29	IS-7.1.1(B)	0.637
217	ST ISMB500	PASS	230.05 C	-37.86	IS-7.1.1(B)	0.577
218	ST ISMB500	PASS	326.38 C	-38.18	IS-7.1.1(A)	0.407
219	ST ISMB500	PASS	313.31 C	-35.72	IS-7.1.1(A)	0.394
220	ST ISMB500	PASS	259.44 C	-37.36	IS-7.1.1(A)	0.346
221	ST ISMB500	PASS	201.66 C	-36.13	IS-7.1.1(A)	0.328
222	ST ISMB300	PASS	162.57 T	5.63	IS-7.1.2	0.252
223	ST ISMB300	PASS	152.70 T	2.80	IS-7.1.2	0.210
224	ST ISMB300	PASS	128.05 T	-2.90	IS-7.1.2	0.182
225	ST ISMB300	PASS	92.88 T	-3.06	IS-7.1.2	0.142
226	ST ISMB450	PASS	14.82 T	28.04	IS-7.1.2	0.137
227	ST ISMB300	PASS	185.69 T	5.64	IS-7.1.2	0.279
228	ST ISMB300	PASS	171.67 T	2.87	IS-7.1.2	0.234
229	ST ISMB300	PASS	164.38 T	-2.82	IS-7.1.2	0.224
230	ST ISMB300	PASS	118.60 T	-3.07	IS-7.1.2	0.173
231	ST ISMB450	PASS	17.06 T	34.74	IS-7.1.2	0.168
232	STAR11011012	PASS	198.91 T	0.00	TENSION	0.265

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
233	STAR11011012	PASS	249.75 C	0.00	COMP	0.732
234	STAR10010010	PASS	123.52 T	0.00	TENSION	0.216
235	STAR10010010	PASS	191.81 C	0.00	COMP	0.618
236	STAR10010010	PASS	100.05 T	0.00	TENSION	0.175
237	STAR10010010	PASS	168.07 C	0.00	COMP	0.542
238	STAR10010010	PASS	25.63 T	0.00	TENSION	0.045
239	STAR10010010	PASS	98.76 C	0.00	COMP	0.318
240	STAR10010010	PASS	74.27 C	0.00	COMP	0.298
241	STAR10010010	PASS	98.39 C	0.00	COMP	0.394
242	STAR11011012	PASS	163.62 T	0.00	TENSION	0.218
243	STAR11011012	PASS	214.44 C	0.00	COMP	0.629
244	STAR10010010	PASS	95.37 T	0.00	TENSION	0.167
245	STAR10010010	PASS	163.58 C	0.00	COMP	0.527
246	STAR10010010	PASS	64.25 T	0.00	TENSION	0.113
247	STAR10010010	PASS	132.05 C	0.00	COMP	0.426
248	STAR10010010	PASS	13.64 T	0.00	TENSION	0.024
249	STAR10010010	PASS	86.77 C	0.00	COMP	0.280
250	STAR10010010	PASS	61.73 C	0.00	COMP	0.247
251	STAR10010010	PASS	83.27 C	0.00	COMP	0.334
252	ISA75X75X8	PASS	35.08 T	0.00	TENSION	0.103
253	ISA75X75X8	PASS	22.43 C	0.00	COMP	0.162
254	ISA75X75X8	PASS	31.56 T	0.00	TENSION	0.092
255	ISA75X75X8	PASS	18.91 C	0.00	COMP	0.137
256	ISA75X75X8	PASS	18.78 T	0.00	TENSION	0.055
257	ISA75X75X8	PASS	5.10 C	0.00	COMP	0.037
258	ISA75X75X8	PASS	16.31 T	0.00	TENSION	0.048
259	ISA75X75X8	PASS	2.64 C	0.00	COMP	0.019
260	ISA75X75X8	PASS	63.37 T	0.00	TENSION	0.186
261	ISA75X75X8	PASS	50.92 C	0.00	COMP	0.368
262	ISA75X75X8	PASS	70.41 T	0.00	TENSION	0.206
263	ISA75X75X8	PASS	57.97 C	0.00	COMP	0.419
264	ISA75X75X8	PASS	18.76 T	0.00	TENSION	0.055
265	ISA75X75X8	PASS	14.92 C	0.00	COMP	0.108
266	ISA75X75X8	PASS	18.32 T	0.00	TENSION	0.054
267	ISA75X75X8	PASS	14.48 C	0.00	COMP	0.105
268	ISA75X75X8	PASS	7.86 C	0.00	COMP	0.057
269	ISA75X75X8	PASS	7.80 C	0.00	COMP	0.056
270	ISA75X75X8	PASS	7.80 C	0.00	COMP	0.056
271	ISA75X75X8	PASS	7.86 C	0.00	COMP	0.057
272	ST ISMB500	PASS	26.03 T	120.97	IS-7.1.2	0.421
273	ST ISMB500	PASS	9.05 T	118.77	IS-7.1.2	0.421
274	ST ISMB500	PASS	41.17 T	128.02	IS-7.1.2	0.477
275	ST ISMB500	PASS	25.12 T	137.47	IS-7.1.2	0.477
276	ST ISMB500	PASS	18.46 T	-61.07	IS-7.1.2	0.563
277	ST ISMB500	PASS	25.95 T	143.02	IS-7.1.2	0.496
278	ST ISMB500	PASS	26.09 T	142.68	IS-7.1.2	0.495
279	ST ISMB500	PASS	10.94 C	111.43	IS-7.1.1(A)	0.603
280	ST ISMB500	PASS	30.71 C	111.84	IS-7.1.1(A)	0.644

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
281	ST ISMB500	PASS	14.74 C	120.52	IS-7.1.1(A)	0.659
282	ST ISMB500	PASS	20.37 C	120.79	IS-7.1.1(A)	0.665
283	ST ISMB500	PASS	23.41 C	131.70	IS-7.1.1(A)	0.729
284	ST ISMB500	PASS	12.30 C	123.48	IS-7.1.1(A)	0.671
285	ST ISMB500	PASS	11.13 C	126.69	IS-7.1.1(A)	0.686
286	ST ISMB500	PASS	12.27 C	90.23	IS-7.1.1(A)	0.495
287	ST ISMB500	PASS	54.55 C	91.61	IS-7.1.1(A)	0.589
288	ST ISMB500	PASS	22.33 T	98.29	IS-7.1.2	0.364
289	ST ISMB500	PASS	13.15 C	95.18	IS-7.1.1(A)	0.521
290	ST ISMB500	PASS	24.67 C	-49.91	IS-7.1.1(A)	0.719
291	ST ISMB500	PASS	12.65 C	94.88	IS-7.1.1(A)	0.518
292	ST ISMB500	PASS	17.87 C	98.43	IS-7.1.1(A)	0.544
293	ST ISMB350	PASS	30.96 T	90.27	IS-7.1.2	0.744
294	ST ISMB350	PASS	16.43 T	90.64	IS-7.1.2	0.730
295	ST ISMB350	PASS	41.24 T	91.12	IS-7.1.2	0.759
296	ST ISMB350	PASS	31.06 T	91.85	IS-7.1.2	0.756
297	ST ISMB350	PASS	27.71 T	92.31	IS-7.1.2	0.751
298	ST ISMB350	PASS	28.27 T	91.11	IS-7.1.2	0.747
299	ST ISMB350	PASS	27.91 T	90.99	IS-7.1.2	0.746
300	ISA75X75X8	PASS	6.72 C	0.00	COMP	0.083
301	ISA75X75X8	PASS	14.10 C	0.00	COMP	0.175
302	ISA75X75X8	PASS	55.05 T	0.00	TENSION	0.161
303	ISA75X75X8	PASS	48.60 T	0.00	TENSION	0.142
304	ISA75X75X8	PASS	62.25 T	0.00	TENSION	0.182
305	ISA75X75X8	PASS	12.37 T	0.00	TENSION	0.036
306	ISA75X75X8	PASS	6.18 T	0.00	TENSION	0.018
307	ISA75X75X8	PASS	6.91 C	0.00	COMP	0.086
308	ISA75X75X8	PASS	14.60 C	0.00	COMP	0.181
309	ISA75X75X8	PASS	7.59 T	0.00	TENSION	0.022
310	ISA75X75X8	PASS	12.92 T	0.00	TENSION	0.038
311	ISA75X75X8	PASS	15.69 T	0.00	TENSION	0.046
312	ISA75X75X8	PASS	9.82 C	0.00	COMP	0.122
313	ISA75X75X8	PASS	3.02 C	0.00	COMP	0.038
314	ISA75X75X8	PASS	17.79 C	0.00	COMP	0.221
315	ISA90X90X8	PASS	34.40 C	0.00	COMP	0.257
316	ISA90X90X8	PASS	120.92 T	0.00	TENSION	0.292
317	ISA75X75X8	PASS	103.60 T	0.00	TENSION	0.304
318	ISA90X90X8	PASS	137.19 T	0.00	TENSION	0.332
319	ISA75X75X8	PASS	46.72 T	0.00	TENSION	0.137
320	ISA75X75X8	PASS	30.05 T	0.00	TENSION	0.088
321	ISA75X75X8	PASS	6.69 C	0.00	COMP	0.083
322	ISA75X75X8	PASS	13.59 C	0.00	COMP	0.169
323	ISA75X75X8	PASS	26.55 T	0.00	TENSION	0.078
324	ISA75X75X8	PASS	19.88 T	0.00	TENSION	0.058
325	ISA75X75X8	PASS	33.42 T	0.00	TENSION	0.098
326	ISA75X75X8	PASS	13.23 T	0.00	TENSION	0.039
327	ISA75X75X8	PASS	6.61 T	0.00	TENSION	0.019
328	ISA75X75X8	PASS	13.43 T	0.00	TENSION	0.039

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
329	ISA75X75X8	PASS	4.67 T	0.00	TENSION	0.014
330	ISA75X75X8	PASS	19.96 T	0.00	TENSION	0.058
331	ISA75X75X8	PASS	11.53 T	0.00	TENSION	0.034
332	ISA75X75X8	PASS	2.78 T	0.00	TENSION	0.008
333	ISA75X75X8	PASS	17.12 T	0.00	TENSION	0.050
334	ISA75X75X8	PASS	7.02 T	0.00	TENSION	0.021
335	ISA75X75X8	PASS	27.21 T	0.00	TENSION	0.080
336	ISA75X75X8	PASS	10.18 C	0.00	COMP	0.074
337	ISA75X75X8	PASS	0.08 C	0.00	COMP	0.001
338	ISA75X75X8	PASS	7.90 C	0.00	COMP	0.057
339	ISA75X75X8	PASS	17.70 C	0.00	COMP	0.128
340	ISA75X75X8	PASS	4.05 T	0.00	TENSION	0.012
341	ISA75X75X8	PASS	9.02 T	0.00	TENSION	0.026
342	ISA75X75X8	PASS	18.82 T	0.00	TENSION	0.055
343	ISA75X75X8	PASS	0.26 T	0.00	TENSION	0.001
344	ISA75X75X8	PASS	6.87 C	0.00	COMP	0.050
345	ISA75X75X8	PASS	7.06 T	0.00	TENSION	0.021
346	ISA75X75X8	PASS	2.73 C	0.00	COMP	0.020
347	ISA75X75X8	PASS	4.40 T	0.00	TENSION	0.013

D.2 DESIGN RESULTS FOR SHORT TERM CASE

ALL UNITS ARE IN KN METER (UNLESS OTHERWISE NOTED)

MEMB	TABLE	RESULT	FX kN	0.00 kN-m	CRIITICAL COND	RATIO
79	ST ISMB500	PASS	43.11 T	214.87	IS-7.1.2	0.780
80	ST ISMB500	PASS	57.72 T	201.34	IS-7.1.2	0.777
81	ST ISMB500	PASS	28.01 T	210.13	IS-7.1.2	0.786
82	ST ISMB500	PASS	43.85 T	220.40	IS-7.1.2	0.766
83	ST ISMB500	PASS	50.57 T	232.34	IS-7.1.2	0.810
84	ST ISMB500	PASS	43.09 T	227.38	IS-7.1.2	0.789
85	ST ISMB500	PASS	42.65 T	227.24	IS-7.1.2	0.789
272	ST ISMB500	PASS	14.73 T	214.95	IS-7.1.1(A)	0.729
273	ST ISMB500	PASS	0.76 C	201.61	IS-7.1.2	1.081
274	ST ISMB500	PASS	29.42 T	210.57	IS-7.1.2	0.744
275	ST ISMB500	PASS	14.17 T	221.33	IS-7.1.2	0.751
276	ST ISMB500	PASS	7.50 T	233.07	IS-7.1.2	0.787
277	ST ISMB500	PASS	14.98 T	227.63	IS-7.1.2	0.773
278	ST ISMB500	PASS	15.04 T	227.28	IS-7.1.2	0.772
99	ST ISMB500	PASS	9.99 T	183.12	IS-7.1.2	0.624
100	ST ISMB500	PASS	14.51 T	179.78	IS-7.1.1(A)	0.703
101	ST ISMB500	PASS	3.40 C	145.90	IS-7.1.2	0.885
102	ST ISMB500	PASS	16.63 T	184.35	IS-7.1.1(A)	0.634
103	ST ISMB500	PASS	30.43 C	-40.31	IS-7.1.2	0.749
104	ST ISMB500	PASS	9.21 T	188.20	IS-7.1.2	0.643
105	ST ISMB500	PASS	8.19 T	191.71	IS-7.1.1(A)	0.655
279	ST ISMB500	PASS	21.28 C	184.75	IS-7.1.1(A)	1.003
280	ST ISMB500	PASS	37.34 C	180.86	IS-7.1.1(A)	1.015

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
281	ST ISMB500	PASS	21.97 C	189.00	IS-7.1.1(A)	1.030
282	ST ISMB500	PASS	27.29 C	186.56	IS-7.1.1(A)	1.021
283	ST ISMB500	PASS	30.43 C	197.80	IS-7.1.1(A)	1.087
284	ST ISMB500	PASS	19.40 C	189.70	IS-7.1.1(A)	1.029
285	ST ISMB500	PASS	19.05 C	192.91	IS-7.1.1(A)	1.046
119	ST ISMB500	PASS	20.75 C	-61.24	IS-7.1.2	0.673
120	ST ISMB500	PASS	39.79 T	153.16	IS-7.1.1(A)	0.697
121	ST ISMB500	PASS	30.82 C	156.93	IS-7.1.1(A)	1.045
122	ST ISMB500	PASS	21.34 C	-60.20	IS-7.1.1(A)	0.685
123	ST ISMB500	PASS	32.87 C	-28.85	IS-7.1.1(A)	0.926
124	ST ISMB500	PASS	20.86 C	-60.44	IS-7.1.1(A)	0.708
125	ST ISMB500	PASS	26.16 C	-62.56	IS-7.1.1(A)	0.731
286	ST ISMB500	PASS	20.75 C	155.97	IS-7.1.1(A)	0.853
287	ST ISMB500	PASS	59.77 C	155.60	IS-7.1.2	0.929
288	ST ISMB500	PASS	11.66 T	161.70	IS-7.1.1(A)	0.567
289	ST ISMB500	PASS	21.34 C	154.77	IS-7.1.1(A)	0.846
290	ST ISMB500	PASS	32.87 C	165.31	IS-7.1.1(A)	0.920
291	ST ISMB500	PASS	20.86 C	154.69	IS-7.1.1(A)	0.844
292	ST ISMB500	PASS	26.16 C	158.26	IS-7.1.2	0.870
139	ST ISMB350	PASS	50.47 T	102.54	IS-7.1.2	0.852
140	ST ISMB350	PASS	58.91 T	100.30	IS-7.1.2	0.844
141	ST ISMB350	PASS	36.32 T	100.84	IS-7.1.2	0.825
142	ST ISMB350	PASS	50.17 T	101.57	IS-7.1.2	0.844
143	ST ISMB350	PASS	48.18 T	103.03	IS-7.1.2	0.858
144	ST ISMB350	PASS	47.62 T	102.05	IS-7.1.2	0.845
145	ST ISMB350	PASS	48.01 T	101.93	IS-7.1.2	0.844
293	ST ISMB350	PASS	21.35 T	105.93	IS-7.1.2	0.855
294	ST ISMB350	PASS	8.43 T	103.70	IS-7.1.2	0.823
295	ST ISMB350	PASS	30.91 T	104.14	IS-7.1.2	0.849
296	ST ISMB350	PASS	21.55 T	105.28	IS-7.1.2	0.850
297	ST ISMB350	PASS	18.20 T	105.76	IS-7.1.2	0.845
298	ST ISMB350	PASS	18.76 T	104.59	IS-7.1.2	0.841
299	ST ISMB350	PASS	18.41 T	104.47	IS-7.1.1(A)	0.840
159	ST ISMB400	PASS	49.83 C	96.58	IS-7.1.1(A)	1.109
160	ST ISMB400	PASS	47.12 C	93.52	IS-7.1.1(A)	1.070
161	ST ISMB400	PASS	47.59 C	94.08	IS-7.1.1(A)	1.077
162	ST ISMB400	PASS	51.47 C	94.35	IS-7.1.1(A)	1.091
163	ST ISMB400	PASS	48.81 C	89.37	IS-7.1.1(A)	1.034
164	ST ISMB400	PASS	48.82 C	88.40	IS-7.1.1(A)	1.024
165	ST ISMB400	PASS	48.73 C	89.00	IS-7.1.1(A)	1.030
1	TB ISMB500	PASS	608.92 C	275.12	IS-7.1.1(A)	0.865
2	TB ISMB500	PASS	920.32 C	256.63	IS-7.1.1(A)	0.999
3	TB ISMB500	PASS	724.16 C	-236.40	IS-7.1.1(A)	0.852
4	TB ISMB500	PASS	780.25 C	286.84	IS-7.1.1(A)	0.982
5	TB ISMB500	PASS	782.89 C	309.40	IS-7.1.1(A)	1.028
6	TB ISMB500	PASS	716.15 C	299.92	IS-7.1.1(B)	0.972
7	TB ISMB500	PASS	602.50 C	299.31	IS-7.1.1(A)	0.916
66	TB ISMB500	PASS	673.91 C	-274.63	IS-7.1.1(A)	0.900

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
67	TB ISMB500	PASS	585.78 C	-252.31	IS-7.1.1(A)	0.808
68	TB ISMB500	PASS	823.48 C	-268.74	IS-7.1.1(A)	0.970
69	TB ISMB500	PASS	663.88 C	-285.81	IS-7.1.1(A)	0.916
70	TB ISMB500	PASS	675.16 C	-307.29	IS-7.1.1(A)	0.964
71	TB ISMB500	PASS	662.51 C	-298.00	IS-7.1.1(B)	0.939
72	TB ISMB500	PASS	584.51 C	-297.36	IS-7.1.1(A)	0.904
166	TB ISMB500	PASS	601.13 C	144.85	IS-7.1.1(A)	0.612
167	TB ISMB500	PASS	578.86 C	136.22	IS-7.1.1(A)	0.721
168	TB ISMB500	PASS	711.55 C	143.76	IS-7.1.1(A)	0.764
169	TB ISMB500	PASS	616.97 C	152.01	IS-7.1.1(A)	0.641
170	TB ISMB500	PASS	628.25 C	164.10	IS-7.1.1(A)	0.709
171	TB ISMB500	PASS	615.60 C	156.42	IS-7.1.1(A)	0.644
172	TB ISMB500	PASS	551.62 C	154.52	IS-7.1.1(A)	0.600
194	TB ISMB500	PASS	576.03 C	-146.46	IS-7.1.1(A)	0.604
195	TB ISMB500	PASS	795.04 C	-139.54	IS-7.1.1(A)	0.815
196	TB ISMB500	PASS	611.97 C	-141.49	IS-7.1.1(A)	0.757
197	TB ISMB500	PASS	733.35 C	-150.45	IS-7.1.1(A)	0.694
198	TB ISMB500	PASS	735.99 C	-163.68	IS-7.1.1(A)	0.744
199	TB ISMB500	PASS	669.25 C	-156.95	IS-7.1.1(A)	0.678
200	TB ISMB500	PASS	569.61 C	-155.78	IS-7.1.1(B)	0.613
173	ST ISMB500	PASS	477.56 C	120.62	IS-7.1.1(B)	0.740
174	TB ISMB500	PASS	476.95 C	124.40	IS-7.1.1(B)	0.444
175	TB ISMB500	PASS	521.56 C	125.19	IS-7.1.1(B)	0.468
176	ST ISMB500	PASS	477.46 C	127.03	IS-7.1.1(B)	0.734
177	ST ISMB500	PASS	483.91 C	127.39	IS-7.1.1(B)	0.988
178	ST ISMB500	PASS	474.48 C	133.24	IS-7.1.1(B)	1.008
179	ST ISMB500	PASS	424.75 C	130.60	IS-7.1.1(B)	0.826
201	ST ISMB500	PASS	452.54 C	-122.53	IS-7.1.1(B)	0.695
202	TB ISMB500	PASS	591.02 C	-120.30	IS-7.1.1(B)	0.466
203	TB ISMB500	PASS	524.27 C	-136.10	IS-7.1.1(B)	0.527
204	ST ISMB500	PASS	594.16 C	-128.39	IS-7.1.1(B)	0.969
205	ST ISMB500	PASS	591.91 C	-127.31	IS-7.1.1(B)	0.887
206	ST ISMB500	PASS	528.24 C	-133.98	IS-7.1.1(B)	0.854
207	ST ISMB500	PASS	442.78 C	-131.05	IS-7.1.1(B)	0.749
27	ST ISMB500	PASS	357.70 C	70.12	IS-7.1.1(B)	0.459
28	TB ISMB500	PASS	496.96 C	68.91	IS-7.1.1(B)	0.332
29	TB ISMB500	PASS	524.36 C	14.58	IS-7.1.1(B)	0.352
30	ST ISMB500	PASS	490.08 C	63.01	IS-7.1.1(B)	0.714
31	ST ISMB500	PASS	490.88 C	78.62	IS-7.1.1(B)	0.628
32	ST ISMB500	PASS	423.10 C	61.70	IS-7.1.1(B)	0.586
33	ST ISMB500	PASS	345.26 C	70.74	IS-7.1.1(B)	0.484
106	ST ISMB500	PASS	382.31 C	-73.78	IS-7.1.1(B)	0.523
107	TB ISMB500	PASS	382.49 C	-65.96	IS-7.1.1(B)	0.297
108	TB ISMB500	PASS	424.58 C	-74.09	IS-7.1.1(B)	0.333
109	ST ISMB500	PASS	372.83 C	-66.88	IS-7.1.1(B)	0.496
110	ST ISMB500	PASS	382.42 C	-80.42	IS-7.1.1(B)	0.607
111	ST ISMB500	PASS	368.96 C	-64.23	IS-7.1.1(B)	0.750
112	ST ISMB500	PASS	326.90 C	-72.48	IS-7.1.1(B)	0.569

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
180	ST ISMB500	PASS	361.97 C	83.04	IS-7.1.1(A)	0.514
181	TB ISMB500	PASS	358.14 C	77.08	IS-7.1.1(A)	0.571
182	TB ISMB500	PASS	357.16 C	91.95	IS-7.1.1(B)	0.557
183	ST ISMB500	PASS	346.31 C	85.84	IS-7.1.1(B)	0.531
184	ST ISMB500	PASS	348.06 C	98.31	IS-7.1.1(B)	0.711
185	ST ISMB500	PASS	342.54 C	86.98	IS-7.1.1(B)	0.519
186	ST ISMB500	PASS	306.57 C	91.55	IS-7.1.1(B)	0.508
208	ST ISMB500	PASS	337.37 C	-82.26	IS-7.1.1(B)	0.763
209	TB ISMB500	PASS	423.82 C	-82.07	IS-7.1.1(B)	0.661
210	TB ISMB500	PASS	409.15 C	-83.49	IS-7.1.1(B)	0.693
211	ST ISMB500	PASS	463.57 C	-82.76	IS-7.1.1(B)	0.821
212	ST ISMB500	PASS	456.53 C	-96.71	IS-7.1.1(B)	0.964
213	ST ISMB500	PASS	396.67 C	-85.20	IS-7.1.1(B)	0.848
214	ST ISMB500	PASS	324.93 C	-91.19	IS-7.1.1(B)	0.807
40	ST ISMB500	PASS	257.28 C	77.27	IS-7.1.1(A)	0.517
41	TB ISMB500	PASS	343.28 C	78.38	IS-7.1.1(A)	0.550
42	TB ISMB500	PASS	327.34 C	81.22	IS-7.1.1(A)	0.584
43	ST ISMB500	PASS	383.66 C	75.04	IS-7.1.1(B)	0.566
44	ST ISMB500	PASS	371.54 C	72.56	IS-7.1.1(B)	0.572
45	ST ISMB500	PASS	316.53 C	73.75	IS-7.1.1(B)	0.578
46	ST ISMB500	PASS	244.01 C	71.67	IS-7.1.1(B)	0.508
126	ST ISMB500	PASS	285.44 C	-80.33	IS-7.1.1(A)	0.487
127	TB ISMB500	PASS	281.39 C	-85.92	IS-7.1.1(A)	0.559
128	TB ISMB500	PASS	278.85 C	-77.75	IS-7.1.1(B)	0.500
129	ST ISMB500	PASS	269.83 C	-76.50	IS-7.1.1(B)	0.451
130	ST ISMB500	PASS	266.70 C	-74.59	IS-7.1.1(B)	0.530
131	ST ISMB500	PASS	266.08 C	-75.25	IS-7.1.1(A)	0.485
132	ST ISMB500	PASS	200.39 C	-74.28	IS-7.1.1(B)	0.438
187	ST ISMB500	PASS	220.75 C	88.74	IS-7.1.1(A)	0.530
188	ST ISMB500	PASS	200.41 C	84.87	IS-7.1.1(A)	0.807
189	ST ISMB500	PASS	191.99 C	86.51	IS-7.1.1(B)	0.757
190	ST ISMB500	PASS	229.70 C	88.42	IS-7.1.1(B)	0.533
191	ST ISMB500	PASS	226.58 C	90.86	IS-7.1.1(B)	0.542
192	ST ISMB500	PASS	225.96 C	88.39	IS-7.1.1(A)	0.536
193	ST ISMB500	PASS	175.59 C	89.35	IS-7.1.1(B)	0.525
215	ST ISMB500	PASS	232.48 C	-92.95	IS-7.1.1(B)	0.540
216	ST ISMB500	PASS	246.41 C	-89.82	IS-7.1.1(B)	0.776
217	ST ISMB500	PASS	246.53 C	-90.82	IS-7.1.1(B)	0.845
218	ST ISMB500	PASS	343.53 C	-91.93	IS-7.1.1(B)	0.600
219	ST ISMB500	PASS	331.41 C	-92.40	IS-7.1.1(B)	0.599
220	ST ISMB500	PASS	276.40 C	-91.23	IS-7.1.1(B)	0.547
221	ST ISMB500	PASS	219.21 C	-91.86	IS-7.1.1(A)	0.518
53	ST ISMB500	PASS	156.76 C	-97.05	IS-7.1.1(A)	0.467
54	ST ISMB500	PASS	161.37 C	46.52	IS-7.1.1(A)	0.655
55	ST ISMB500	PASS	169.72 C	26.17	IS-7.1.1(A)	0.625
56	ST ISMB500	PASS	267.87 C	-94.88	IS-7.1.1(A)	0.585
57	ST ISMB500	PASS	255.38 C	-89.90	IS-7.1.1(A)	0.556
58	ST ISMB500	PASS	200.62 C	-88.89	IS-7.1.1(A)	0.492

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
59	ST ISMB500	PASS	143.63 C	-89.50	IS-7.1.1(A)	0.430
146	ST ISMB500	PASS	144.19 C	91.15	IS-7.1.1(A)	0.435
147	ST ISMB500	PASS	122.79 C	-34.18	IS-7.1.1(A)	0.606
148	ST ISMB500	PASS	105.57 C	-51.29	IS-7.1.1(A)	0.652
149	ST ISMB500	PASS	153.11 C	89.66	IS-7.1.1(A)	0.441
150	ST ISMB500	PASS	149.88 C	86.85	IS-7.1.1(A)	0.429
151	ST ISMB500	PASS	149.54 C	85.51	IS-7.1.1(A)	0.424
152	ST ISMB500	PASS	99.40 C	86.07	IS-7.1.1(A)	0.416
8	ST ISMB300	PASS	49.07 C	-39.98	IS-7.1.1(A)	0.824
9	ST ISMB300	PASS	254.22 C	5.63	IS-7.1.1(A)	1.005
10	ST ISMB300	PASS	9.45 C	-39.98	IS-7.1.1(A)	0.776
11	ST ISMB300	PASS	7.89 C	-39.98	IS-7.1.1(A)	0.770
12	ST ISMB300	PASS	4.86 C	-39.98	IS-7.1.1(A)	0.760
13	ST ISMB300	PASS	1.97 C	-39.98	IS-7.1.1(A)	0.749
73	ST ISMB400	PASS	60.84 C	-72.39	IS-7.1.1(A)	0.819
74	ST ISMB300	PASS	244.73 C	5.63	IS-7.1.1(A)	0.971
75	ST ISMB300	PASS	12.21 C	-39.98	IS-7.1.1(A)	0.786
76	ST ISMB300	PASS	8.95 C	-39.98	IS-7.1.1(A)	0.774
77	ST ISMB300	PASS	3.86 C	-39.98	IS-7.1.1(A)	0.756
78	ST ISMB300	PASS	2.68 C	-39.98	IS-7.1.1(A)	0.752
222	ST ISMB300	PASS	198.21 C	5.43	IS-7.1.1(A)	0.799
227	ST ISMB300	PASS	215.78 C	5.83	IS-7.1.1(A)	0.870
21	ST ISMB300	PASS	38.67 C	-39.98	IS-7.1.1(A)	0.879
22	ST ISMB300	PASS	204.66 C	3.34	IS-7.1.1(A)	0.785
23	ST ISMB300	PASS	11.58 C	-39.98	IS-7.1.1(A)	0.783
24	ST ISMB300	PASS	2.56 C	-39.98	IS-7.1.1(A)	0.751
25	ST ISMB300	PASS	1.67 C	-39.98	IS-7.1.1(A)	0.748
26	ST ISMB300	PASS	3.23 C	-39.98	IS-7.1.1(A)	0.754
93	ST ISMB300	PASS	47.90 C	-39.98	IS-7.1.1(A)	0.820
94	ST ISMB300	PASS	186.47 C	3.40	IS-7.1.1(A)	0.721
95	ST ISMB300	PASS	27.29 C	-39.98	IS-7.1.1(A)	0.839
96	ST ISMB300	PASS	28.11 C	-39.98	IS-7.1.1(A)	0.842
97	ST ISMB300	PASS	18.94 C	-39.98	IS-7.1.1(A)	0.809
98	ST ISMB300	PASS	5.79 C	-39.98	IS-7.1.1(A)	0.763
223	ST ISMB300	PASS	170.53 C	2.84	IS-7.1.1(A)	0.654
228	ST ISMB300	PASS	193.57 C	2.99	IS-7.1.1(A)	0.739
34	ST ISMB300	PASS	32.57 C	-39.98	IS-7.1.1(A)	0.858
35	ST ISMB300	PASS	161.80 C	2.81	IS-7.1.1(A)	0.622
36	ST ISMB300	PASS	40.99 C	-39.98	IS-7.1.1(A)	0.888
37	ST ISMB300	PASS	26.17 C	-39.98	IS-7.1.1(A)	0.835
38	ST ISMB300	PASS	16.70 C	-39.98	IS-7.1.1(A)	0.802
39	ST ISMB300	PASS	10.36 C	-39.98	IS-7.1.1(A)	0.779
113	ST ISMB300	PASS	22.68 C	-39.98	IS-7.1.1(A)	0.823
114	ST ISMB300	PASS	134.76 C	2.94	IS-7.1.1(A)	0.528
115	ST ISMB300	PASS	27.23 C	-39.98	IS-7.1.1(A)	0.839
116	ST ISMB300	PASS	27.83 C	-39.98	IS-7.1.1(A)	0.841
117	ST ISMB300	PASS	17.04 C	-39.98	IS-7.1.1(A)	0.803
118	ST ISMB300	PASS	5.07 C	-39.98	IS-7.1.1(A)	0.760

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
224	ST ISMB300	PASS	127.91 C	2.86	IS-7.1.1(A)	0.502
229	ST ISMB300	PASS	171.12 C	2.79	IS-7.1.1(A)	0.655
47	ST ISMB300	PASS	41.00 C	-45.20	IS-7.1.1(A)	0.985
48	ST ISMB300	PASS	76.37 C	-2.96	IS-7.1.1(A)	0.319
49	ST ISMB300	PASS	18.32 C	-45.20	IS-7.1.1(A)	0.904
50	ST ISMB300	PASS	14.11 C	-45.20	IS-7.1.1(A)	0.889
51	ST ISMB300	PASS	13.22 C	-45.20	IS-7.1.1(A)	0.886
52	ST ISMB300	PASS	6.24 C	-45.20	IS-7.1.1(A)	0.862
133	ST ISMB400	PASS	49.00 C	-77.01	IS-7.1.1(A)	0.943
134	ST ISMB300	PASS	65.07 C	-3.00	IS-7.1.1(A)	0.280
135	ST ISMB300	PASS	5.13 C	-45.20	IS-7.1.1(A)	0.858
136	ST ISMB300	PASS	2.74 C	-45.20	IS-7.1.1(A)	0.849
137	ST ISMB300	PASS	2.83 C	-45.20	IS-7.1.1(A)	0.849
138	ST ISMB300	PASS	1.98 C	-45.20	IS-7.1.2	0.846
225	ST ISMB300	PASS	129.52 T	-3.00	IS-7.1.1(A)	0.185
230	ST ISMB300	PASS	53.69 C	-2.87	IS-7.1.1(A)	0.237
60	ST ISMB450	PASS	104.56 C	-161.59	IS-7.1.1(A)	1.078
61	ST ISMB450	PASS	100.81 C	35.50	IS-7.1.1(A)	0.328
62	ST ISMB450	PASS	6.51 C	-161.59	IS-7.1.1(A)	0.963
63	ST ISMB450	PASS	5.04 C	-145.08	IS-7.1.1(A)	0.863
64	ST ISMB450	PASS	1.49 C	-145.08	IS-7.1.1(A)	0.859
65	ST ISMB450	PASS	0.70 C	-145.08	IS-7.1.1(A)	0.858
153	ST ISMB500	PASS	70.78 C	-171.34	IS-7.1.1(A)	0.768
154	ST ISMB450	PASS	68.63 C	28.79	IS-7.1.1(A)	0.251
155	ST ISMB450	PASS	4.37 C	-131.85	IS-7.1.1(A)	0.784
156	ST ISMB450	PASS	3.32 C	-126.90	IS-7.1.1(A)	0.754
157	ST ISMB450	PASS	2.23 C	-126.90	IS-7.1.1(A)	0.753
158	ST ISMB450	PASS	1.01 C	-126.90	IS-7.1.1(A)	0.751
226	ST ISMB450	PASS	8.43 C	27.34	IS-7.1.1(A)	0.172
231	ST ISMB450	PASS	7.54 C	35.49	COMP	0.219
300	ISA75X75X8	PASS	6.82 C	0.00	COMP	0.085
301	ISA75X75X8	PASS	14.22 C	0.00	COMP	0.177
302	ISA75X75X8	PASS	54.85 C	0.00	COMP	0.681
303	ISA75X75X8	PASS	48.45 C	0.00	COMP	0.602
304	ISA75X75X8	PASS	62.05 C	0.00	COMP	0.771
305	ISA75X75X8	PASS	12.27 C	0.00	COMP	0.152
306	ISA75X75X8	PASS	6.13 C	0.00	COMP	0.076
307	ISA75X75X8	PASS	7.01 C	0.00	COMP	0.087
308	ISA75X75X8	PASS	14.72 C	0.00	COMP	0.183
309	ISA75X75X8	PASS	1.84 C	0.00	COMP	0.023
310	ISA75X75X8	PASS	11.83 C	0.00	COMP	0.147
311	ISA75X75X8	PASS	9.96 C	0.00	COMP	0.124
312	ISA75X75X8	PASS	10.13 C	0.00	COMP	0.126
313	ISA75X75X8	PASS	3.18 C	0.00	COMP	0.040
314	ISA75X75X8	PASS	17.88 C	0.00	COMP	0.222
315	ISA90X90X8	PASS	34.50 C	0.00	COMP	0.258
316	ISA90X90X8	PASS	120.62 C	0.00	COMP	0.901
317	ISA75X75X8	PASS	103.37 C	0.00	COMP	1.284

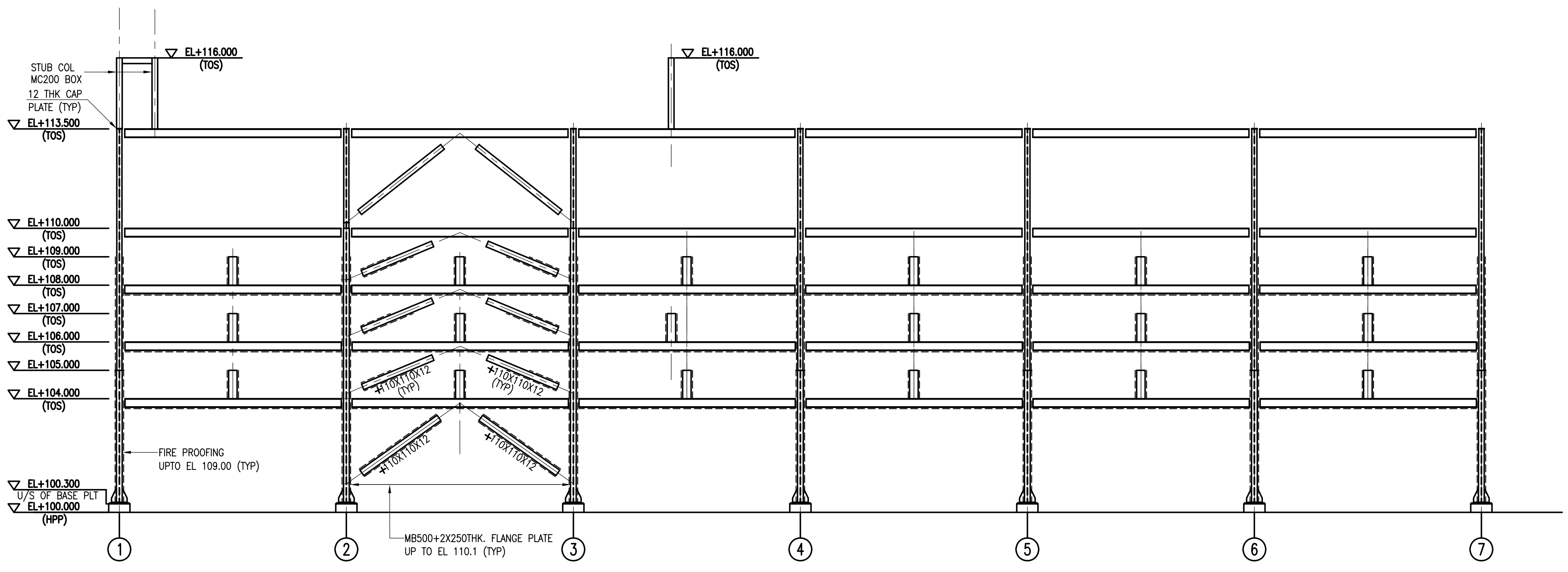
MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
318	ISA90X90X8	PASS	136.76 C	0.00	COMP	1.022
319	ISA75X75X8	PASS	46.57 C	0.00	COMP	0.579
320	ISA75X75X8	PASS	29.97 C	0.00	COMP	0.372
321	ISA75X75X8	PASS	6.73 C	0.00	COMP	0.084
322	ISA75X75X8	PASS	13.63 C	0.00	COMP	0.169
323	ISA75X75X8	PASS	26.45 C	0.00	COMP	0.329
324	ISA75X75X8	PASS	19.81 C	0.00	COMP	0.246
325	ISA75X75X8	PASS	33.34 C	0.00	COMP	0.414
326	ISA75X75X8	PASS	13.18 C	0.00	COMP	0.164
327	ISA75X75X8	PASS	6.58 C	0.00	COMP	0.082
330	ISA75X75X8	PASS	18.87 C	0.00	COMP	0.234
335	ISA75X75X8	PASS	26.62 C	0.00	COMP	0.331
340	ISA75X75X8	PASS	3.72 C	0.00	COMP	0.046
345	ISA75X75X8	PASS	7.07 C	0.00	COMP	0.088
252	ISA75X75X8	PASS	22.80 C	0.00	COMP	0.165
253	ISA75X75X8	PASS	26.07 C	0.00	COMP	0.188
254	ISA75X75X8	PASS	18.28 C	0.00	COMP	0.132
255	ISA75X75X8	PASS	21.50 C	0.00	COMP	0.155
256	ISA75X75X8	PASS	9.53 C	0.00	COMP	0.069
257	ISA75X75X8	PASS	7.55 C	0.00	TENSION	0.055
258	ISA75X75X8	PASS	16.31 T	0.00	COMP	0.048
259	ISA75X75X8	PASS	4.71 C	0.00	COMP	0.034
260	ISA75X75X8	PASS	52.54 C	0.00	COMP	0.380
261	ISA75X75X8	PASS	54.52 C	0.00	COMP	0.394
262	ISA75X75X8	PASS	58.27 C	0.00	COMP	0.421
263	ISA75X75X8	PASS	60.69 C	0.00	COMP	0.438
264	ISA75X75X8	PASS	14.72 C	0.00	COMP	0.106
265	ISA75X75X8	PASS	15.61 C	0.00	COMP	0.113
266	ISA75X75X8	PASS	14.21 C	0.00	COMP	0.103
267	ISA75X75X8	PASS	15.31 C	0.00	COMP	0.111
268	ISA75X75X8	PASS	13.42 C	0.00	COMP	0.097
269	ISA75X75X8	PASS	11.22 C	0.00	COMP	0.081
270	ISA75X75X8	PASS	11.22 C	0.00	COMP	0.081
271	ISA75X75X8	PASS	13.42 C	0.00	COMP	0.097
328	ISA75X75X8	PASS	20.63 C	0.00	COMP	0.149
329	ISA75X75X8	PASS	8.60 C	0.00	COMP	0.062
331	ISA75X75X8	PASS	16.57 C	0.00	COMP	0.120
332	ISA75X75X8	PASS	4.16 C	0.00	COMP	0.030
333	ISA75X75X8	PASS	19.49 C	0.00	COMP	0.141
334	ISA75X75X8	PASS	8.86 C	0.00	COMP	0.064
336	ISA75X75X8	PASS	11.87 C	0.00	COMP	0.086
337	ISA75X75X8	PASS	2.20 C	0.00	COMP	0.016
338	ISA75X75X8	PASS	9.07 C	0.00	COMP	0.066
339	ISA75X75X8	PASS	18.93 C	0.00	COMP	0.137
341	ISA75X75X8	PASS	11.14 C	0.00	COMP	0.080
342	ISA75X75X8	PASS	21.15 C	0.00	COMP	0.153
343	ISA75X75X8	PASS	3.45 C	0.00	COMP	0.025
344	ISA75X75X8	PASS	10.54 C	0.00	COMP	0.076

MEMB	TABLE	RESULT	FX kN	MZ kN-m	CRIITICAL COND	RATIO
346	ISA75X75X8	PASS	3.58 C	0.00	COMP	0.026
347	ISA75X75X8	PASS	8.97 C	0.00	COMP	0.065
234	STAR10010010	PASS	284.45 C	0.00	COMP	0.917
235	STAR10010010	PASS	284.73 C	0.00	COMP	0.918
244	STAR10010010	PASS	261.53 C	0.00	COMP	0.843
245	STAR10010010	PASS	262.73 C	0.00	COMP	0.847
236	STAR10010010	PASS	256.14 C	0.00	COMP	0.826
237	STAR10010010	PASS	255.89 C	0.00	COMP	0.825
246	STAR10010010	PASS	208.74 C	0.00	COMP	0.673
247	STAR10010010	PASS	209.43 C	0.00	COMP	0.675
238	STAR10010010	PASS	177.52 C	0.00	COMP	0.572
239	STAR10010010	PASS	176.75 C	0.00	COMP	0.570
248	STAR10010010	PASS	147.57 C	0.00	COMP	0.476
249	STAR10010010	PASS	147.48 C	0.00	COMP	0.475
240	STAR10010010	PASS	166.62 C	0.00	COMP	0.668
241	STAR10010010	PASS	166.84 C	0.00	COMP	0.669
250	STAR10010010	PASS	130.20 C	0.00	COMP	0.522
251	STAR10010010	PASS	177.52 C	0.00	COMP	0.526

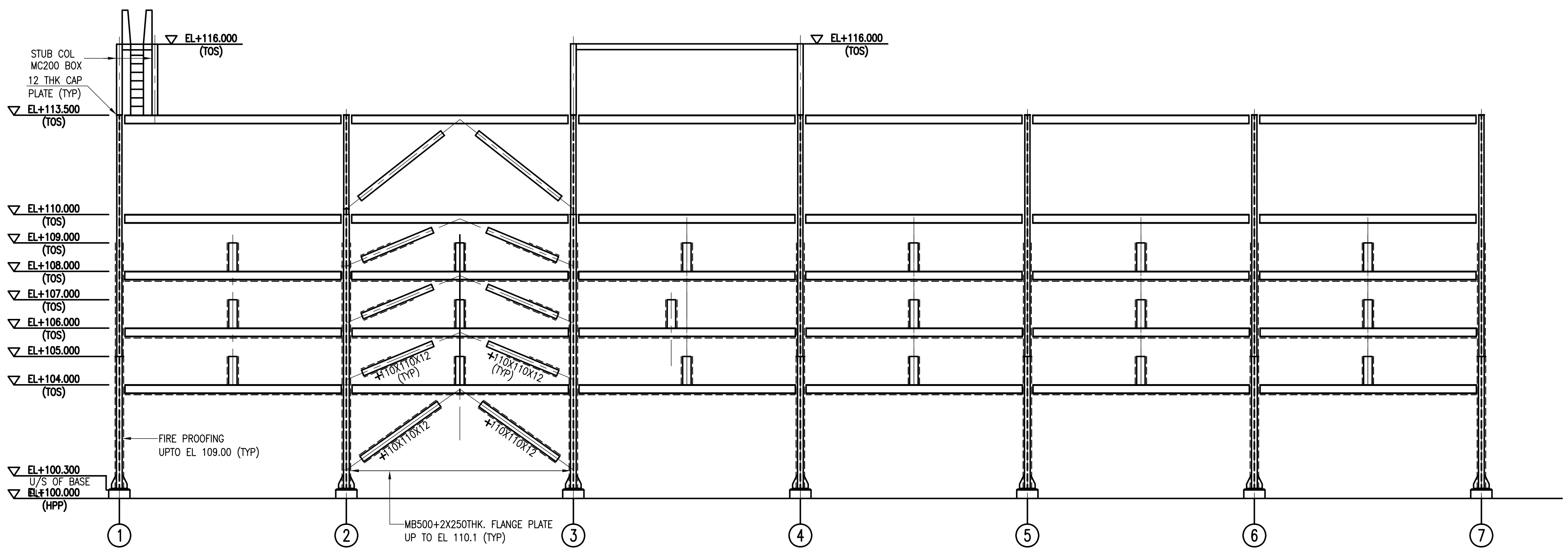
APPENDIX E STRUCTURAL DETAIL DARWINGS

Appendix E consists of detail structural drawings for pipe rack considering 50 m/s wind speed, following is the list of drawings

1. MP/PR-1/ST/1 – Framing Elevation on grid M & L.
2. MP/PR-1/ST/2 – Framing Elevation on grid 1 to 7.
3. MP/PR-1/ST/3 – Plan at EL 105.00, 107.00, 109.00.
4. MP/PR-1/ST/4 – Plan at EL 110.00, 113.5.
5. MP/PR-1/ST/5 – Beam Moment connection.
6. MP/PR-1/ST/6 – Beam shear connection.



ELEVATION ON GRID M



ELEVATION ON GRID L

GENERAL NOTES

1. ALL DIMENSIONS SHALL BE IN MILLIMETRES & LEVELS SHALL BE IN METRES.
2. HIGHEST POINT OF PAVEMENT (HPP) CORRESPONDS TO EL 100.000 AND EL. 100.000 CORRESPONDS TO RL 238.720 M.
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4. ALL ELEVATIONS INDICATED ON DRAWINGS REFER TO TOP OF STEEL. (TOS)
5. ALL STRUCTURAL STEEL MATERIAL SHALL BE OF GRADE A AND SHALL CONFORM TO IS: 2062.
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8. ALL MS GRATING SHALL BE 25MM THICK ELECTROFORGED, HOT DIPPED GALVANIZED AS PER LTC STD DRG. NO. 4644–30016–72–CV–DW–0504.
9. ALL GUSSETS, RIBS, STIFFENERS, ETC, SHALL HAVE MINIMUM THICKNESS 8mm.
10. CHEQUERED PLATES AND GRATINGS SHALL HAVE A MINIMUM BEARING OF 40MM AT EACH SUPPORT.
11. CHEQUERED PLATES SHALL BE TACK WELDED TO FLOOR BEAMS.
12. ALL FILLET WELDS SHALL BE OF MINIMUM 6MM SIZE FOR SHOP WELD AND8MM FOR SITE WELD.
13. ALL BUTT WELDS SHALL BE FULL STRENGTH BUTT WELDS, WITH REQUISITE EDGEPREPARATION FOR THICKNESS MORE THAN 8MM.
14. ALL CONNECTIONS SHALL BE OF WELDED TYPE EXCEPT FOR PURLINS, SIDE RUNNERS, LOUVERS, JOISTS, PLAN BRACINGS, REMOVABLE PLATFORM ETC.
15. SHEAR CONNECTION OF BEAMS SHALL BE DESIGNED FOR 1.2 x DESIGN SHEAR OR 60% OF BEAM SHEAR CAPACITY OF MEMBER WHICHEVER IS HIGHER.
16. MOMENT CONNECTION SHALL BE DESIGNED FOR 100% OF MOMENT CAPACITY AND 60% OF SHEAR CAPACITY FOR SECTION DEPTH 200MMAND ABOVE & 50% OFSHEAR CAPACITY FOR SECTION DEPTH LESS THAN 200MM OR FOR ACTUAL DESIGNFORCES WHICHEVER IS HIGHER.
17. SPLICES SHALL BE DESIGNED TO TRANSFER 1.05 TIMES FULL MEMBER SPLICED.
18. SPLICES IN ROOF PURLINS SHALL BE STAGGERED.
19. CUT OUTS IN FLOORING UPTO 300MM X 300MM OR 300 DIA.
20. ALL LIFTING BEAMS/MONORAILS/CRANE GIRDERS SHALL BE CLEARLY PAINTED INDICATING ITS LIFTING CAPACITY.
21. (+) INDICATES TENSION AND (–) INDICATES AXIAL COMPRESSION FORCES INMEMBERS.
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27. ALL WELDS SHALL BE CONTINUOUS FILLET WELD UNO.

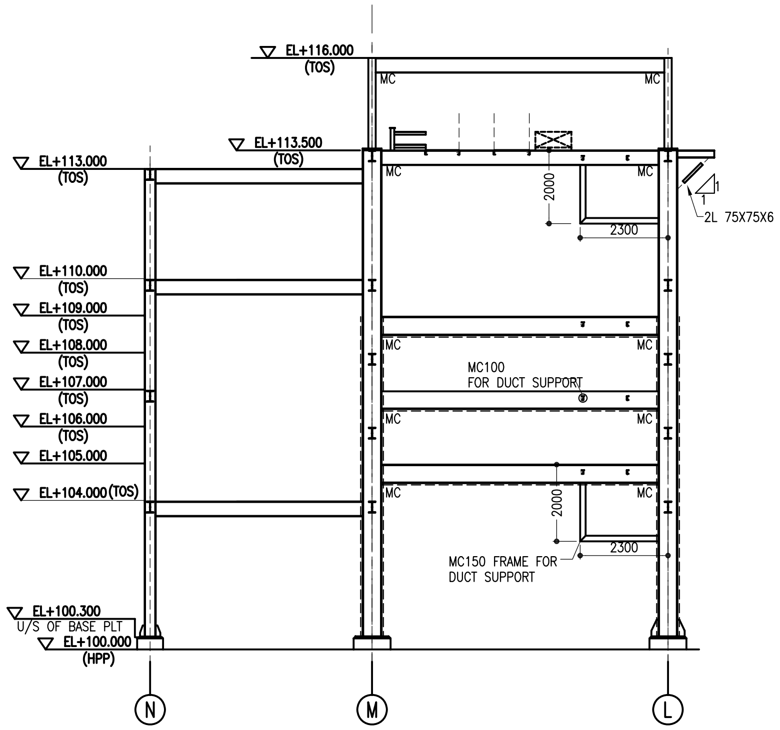
DATE			
BY	SMS	SMS	KMP
	DRAWN	DSGND	CHKD

L&T–CHIYODA LIMITED
BARODA

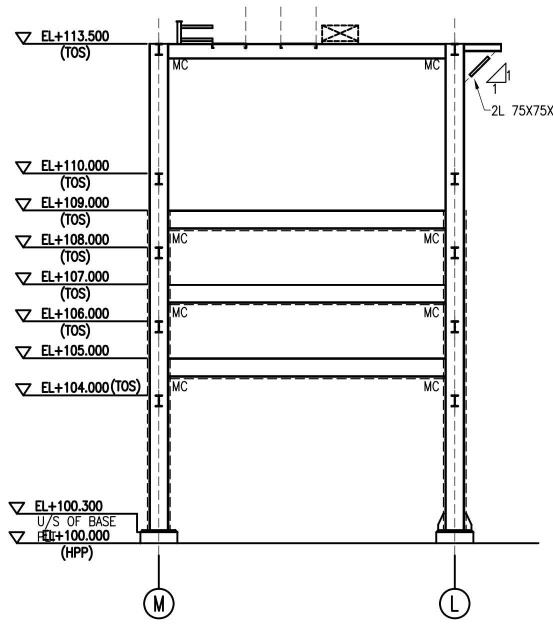
PROJECT
ANALYSIS & DESIGN OF PIPERACK SUPERSTRUCTURE

TITLE
FRAMING ELEVATION ON GRID M & L

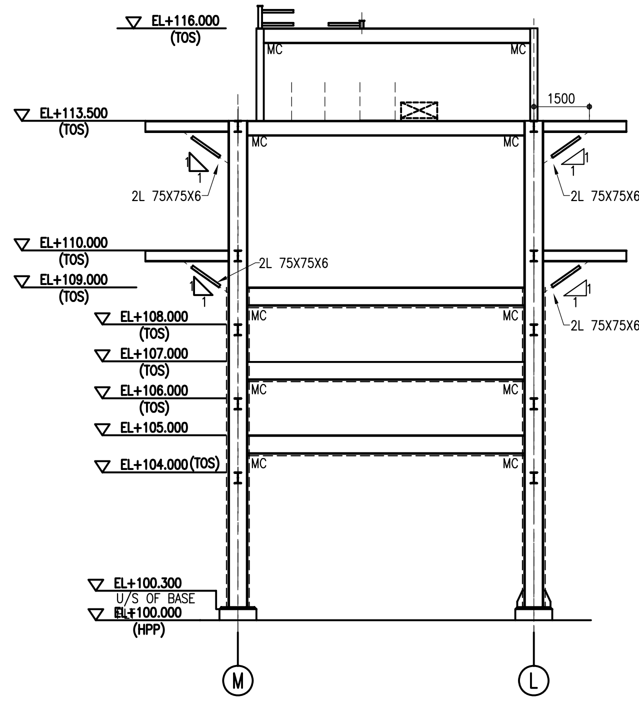
SCALE		JOB NO.
PROJECT	DRAWING NO.	REVISION
MP	MP/PR-1/ST/1	0



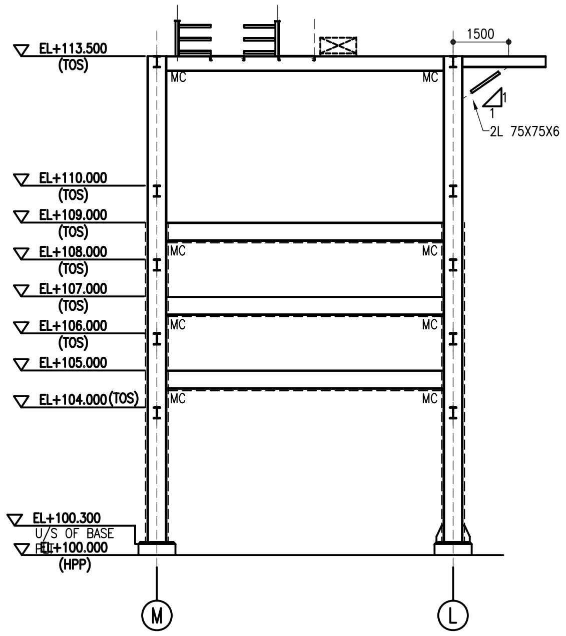
ELEVATION ON GRID 1



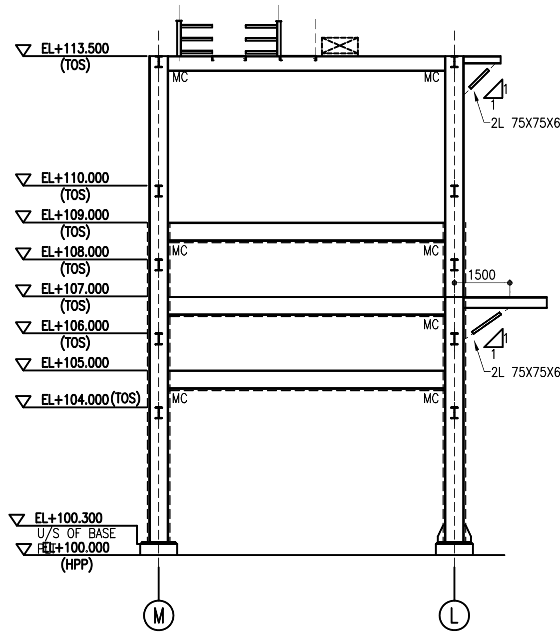
ELEVATION ON GRID 2



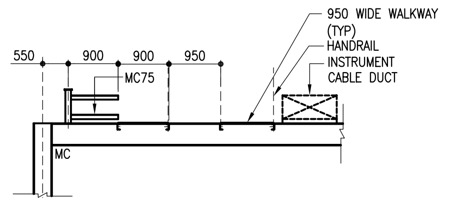
ELEVATION ON GRID 3 & 4



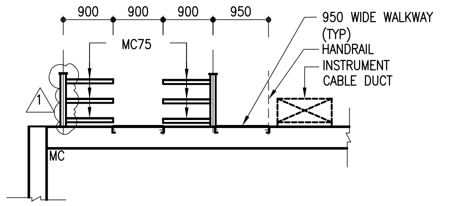
ELEVATION ON GRID 5



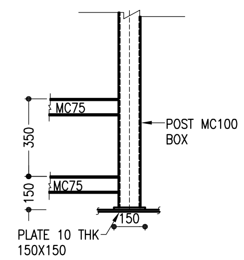
ELEVATION ON GRID 6 & 7



ELEVATION ON GRID 1 & 2



ELEVATION ON GRID 5, 6 & 7



DETAIL 1

GENERAL NOTES

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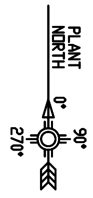
DATE			
BY	SMS	SMS	KMP
	DRAWN	DSGND	CHKD

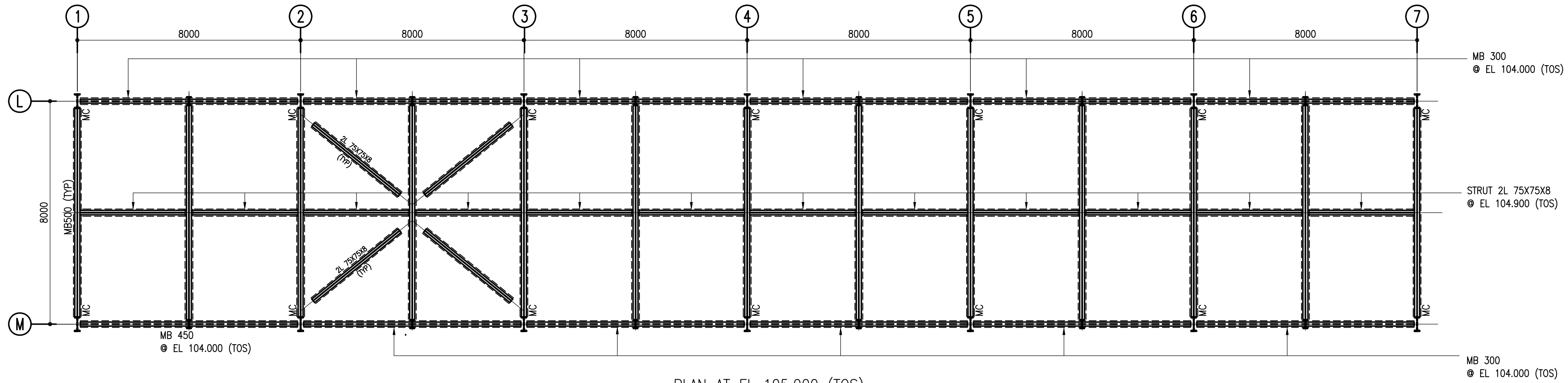
L&T–CHIYODA LIMITED
BARODA

PROJECT
ANALYSIS & DESIGN OF PIPERACK SUPERSTRUCTURE

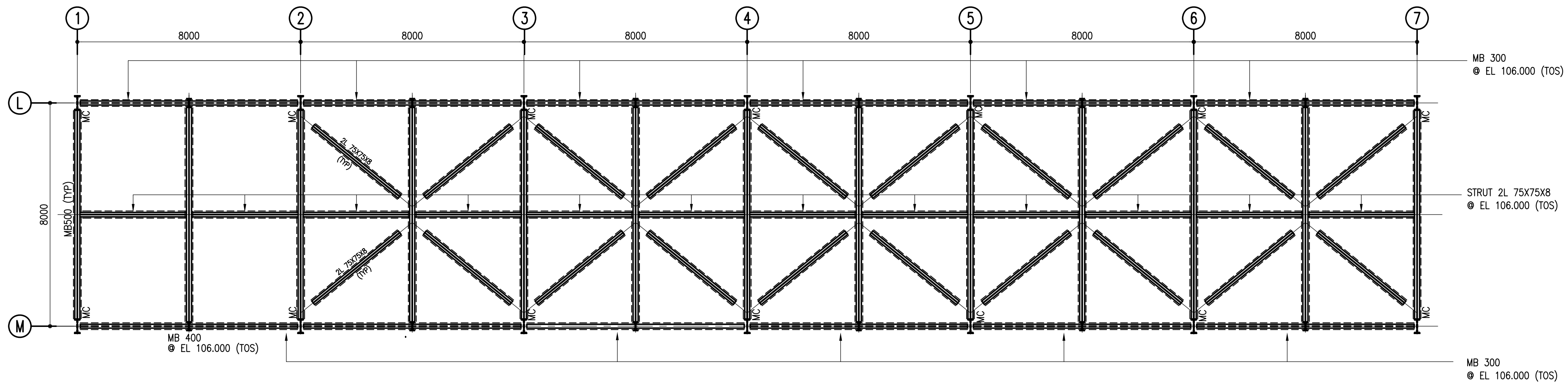
TITLE
FRAMING ELEVATION ON GRID 1 TO 7

SCALE		JOB NO.
PROJECT	DRAWING NO.	REVISION
MP	MP/PR–1/ST/2	0

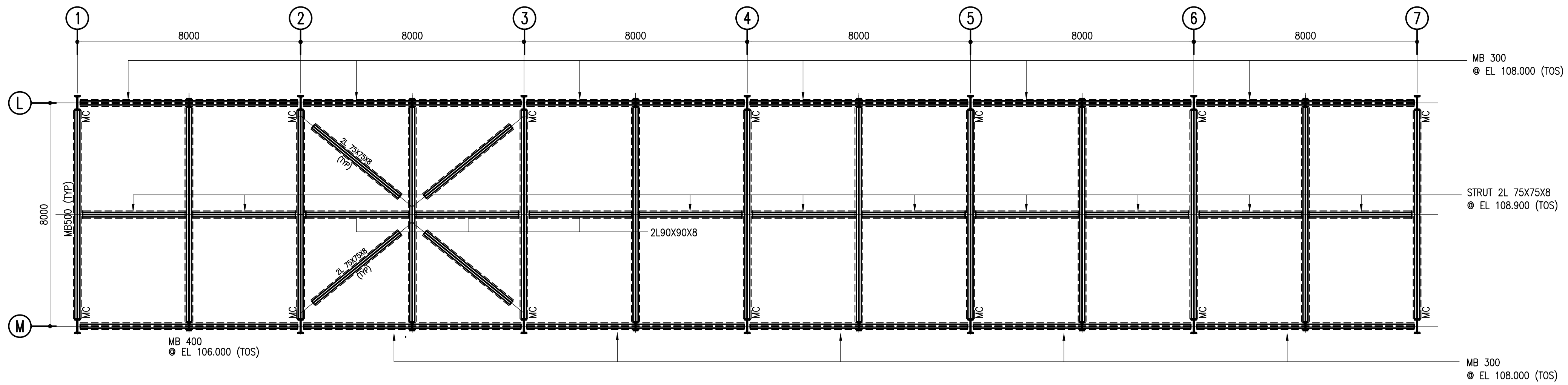




PLAN AT EL 105.000 (TOS)
PLAN BRACING 2L 75X75X8 @ EL 104.90 (TOS)



PLAN AT EL 107.000 (TOS)
PLAN BRACING 2L 75X75X8 @ EL 106.90 (TOS)



PLAN AT EL 109.000 (TOS)
PLAN BRACING 2L 75X75X8 @ EL 108.90 (TOS)

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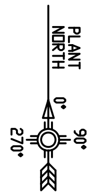
DATE			
BY	SMS	SMS	KMP
	DRAWN	DSGND	CHKD

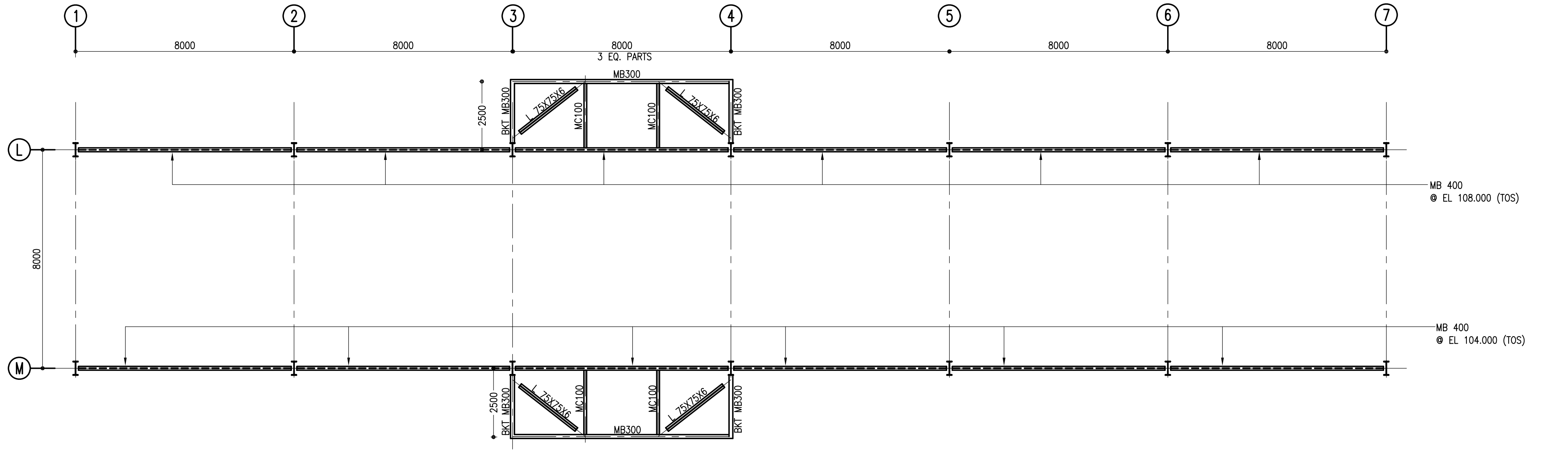
L&T–CHIYODA LIMITED
BARODA

PROJECT
ANALYSIS & DESIGN OF PIPERACK SUPERSTRUCTURE

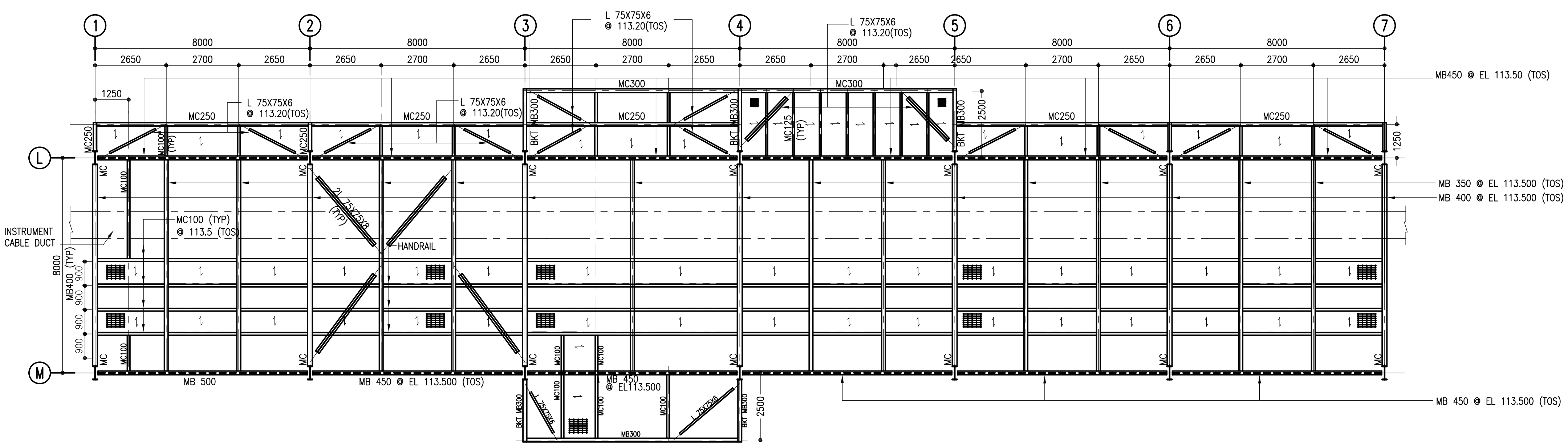
TITLE
PLAN AT EL 105.00, 107.00 & 109.00

SCALE	JOB NO.	
PROJECT	DRAWING NO.	REVISION
MP	MP/PR-1/ST/3	0





PLAN AT EL 110.000 (TOS)



PLAN AT EL 113.500 (TOS)

GENERAL NOTES

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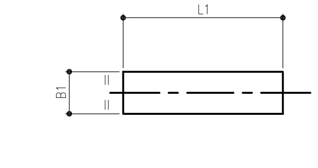
DATE			
BY	SMS	SMS	KMP
	DRAWN	DSGND	CHKD

L&T–CHIYODA LIMITED
BARODA

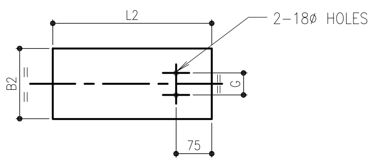
PROJECT
ANALYSIS & DESIGN OF PIPERACK SUPERSTRUCTURE

TITLE
PLAN AT EL 110.00 & 113.50

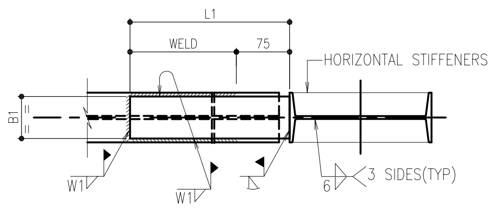
SCALE	JOB NO.	
PROJECT	DRAWING NO.	REVISION
MP	MP/PR–1/ST/4	0



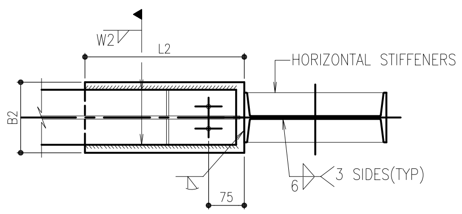
TOP PLATE



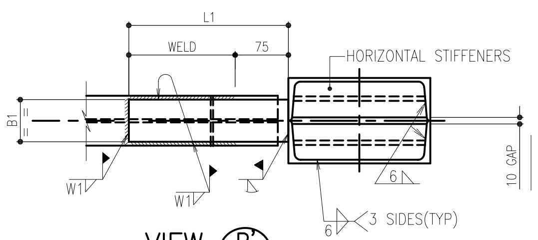
BOTTOM PLATE



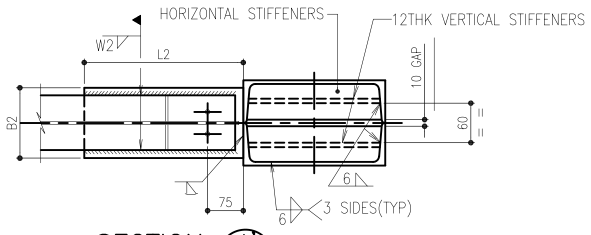
VIEW B



SECTION A

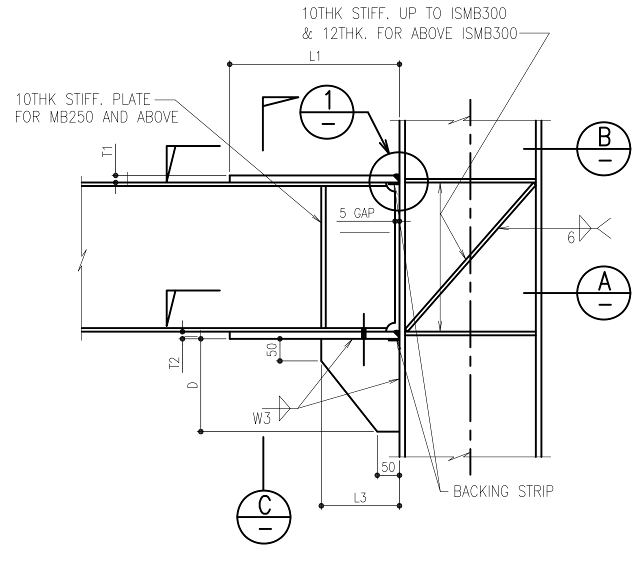


VIEW B'

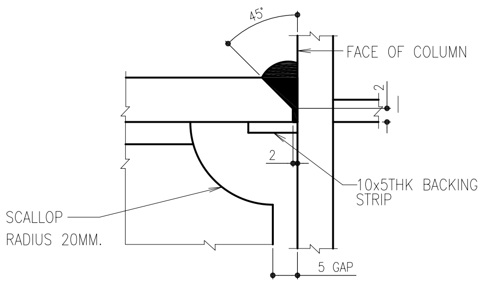


SECTION A'

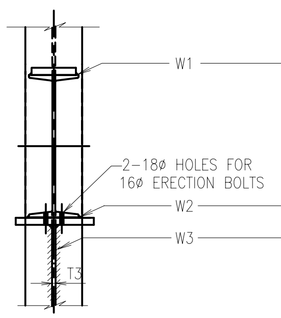
BEAM SIZE	TOP PLATE					BOTTOM PLATE				BEARING PLATE				MOMENT CAPACITY kN-m	SHEAR CAPACITY kN
	L1	B1	T1	W1	G	L2	B2	T2	W2	L3	D	T3	W3		
ISMB200	225	80	20	8	55	225	130	20	8	200	225	10	6	36	68
ISMB250	300	105	22	8	65	300	155	22	8	200	300	10	6	67	103
ISMB300	350	120	22	8	80	350	170	22	8	200	350	10	6	94	135
ISMB350	400	120	28	8	80	400	170	28	8	200	325	12	8	128	170
ISMB400	450	120	32	8	80	450	170	32	8	200	375	12	8	168	213
ISMB450	525	130	32	8	90	525	180	32	8	250	450	12	8	222	253
ISMB500	625	160	32	8	100	625	210	32	8	250	500	12	8	298	306
ISMB600	700	190	38	10	140	700	240	38	10	300	675	12	8	505	432



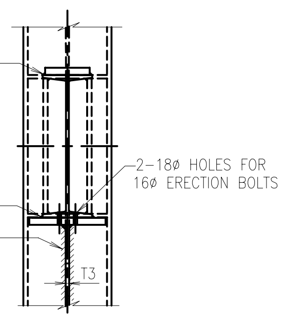
TYPICAL MOMENT CONNECTION
FOR ISMB BEAM TO ISMB COLUMN



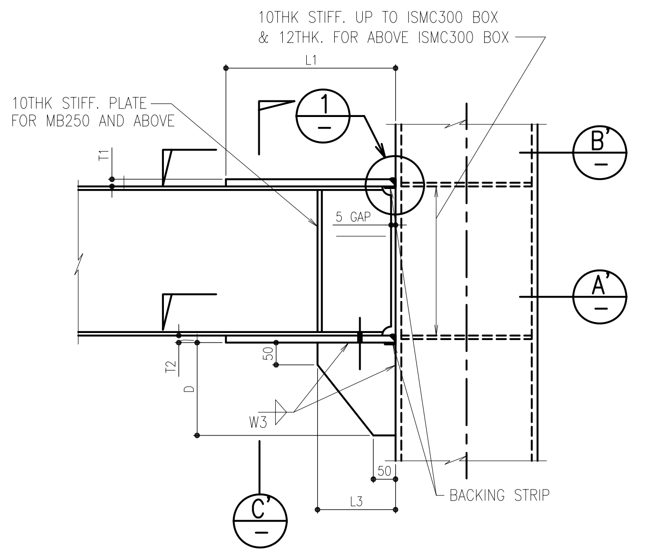
DETAIL 1



SECTION C



SECTION C'



TYPICAL MOMENT CONNECTION
FOR ISMB BEAM TO BOX COLUMN

GENERAL NOTES

1. ALL DIMENSIONS SHALL BE IN MILLIMETRES & LEVELS SHALL BE IN METRES.
2. HIGHEST POINT OF PAVEMENT (HPP) CORRESPONDS TO EL 100.000 AND EL. 100.000 CORRESPONDS TO RL 238.720 M.
3. ALL STRUCTURAL STEEL WORK SHALL BE IN ACCORDANCE WITH SPECIFICATION.
4. ALL ELEVATIONS INDICATED ON DRAWINGS REFER TO TOP OF STEEL. (TOS)
5. ALL STRUCTURAL STEEL MATERIAL SHALL BE OF GRADE A AND SHALL CONFORM TO IS: 2062.
6. ALL ORDINARY STRENGH BOLT SHALL CONFORM TO IS 1367-1980 PROPERTY CLASS 4.6, AND ALL HIGH STRENGTH BOLT SHALL CONFORM TO IS 1367-1980 PROPERTY CLASS 8.8.
7. ALL CHEQUERED PLATES SHALL BE 6MM THICK (ON PLAIN)
8. ALL MS GRATING SHALL BE 25MM THICK ELECTROFORGED, HOT DIPPED GALVANIZED AS PER LTC STD DRG. NO. 4644-30016-72-CV-DW-0504.
9. ALL GUSSETS, RIBS, STIFFENERS, ETC, SHALL HAVE MINIMUM THICKNESS 8mm.
10. CHEQUERED PLATES AND GRATINGS SHALL HAVE A MINIMUM BEARING OF 40MM AT EACH SUPPORT.
11. CHEQUERED PLATES SHALL BE TACK WELDED TO FLOOR BEAMS.
12. ALL FILLET WELDS SHALL BE OF MINIMUM 6MM SIZE FOR SHOP WELD AND8MM FOR SITE WELD.
13. ALL BUTT WELDS SHALL BE FULL STRENGTH BUTT WELDS, WITH REQUISITE EDGEPREPARATION FOR THICKNESS MORE THAN 8MM.
14. ALL CONNECTIONS SHALL BE OF WELDED TYPE EXCEPT FOR PURLINS, SIDE RUNNERS, LOUVERS, JOISTS, PLAN BRACINGS, REMOVABLE PLATFORM ETC.
15. SHEAR CONNECTION OF BEAMS SHALL BE DESIGNED FOR 1.2 x DESIGN SHEAR OR 60% OF BEAM SHEAR CAPACITY OF MEMBER WHICHEVER IS HIGHER.
16. MOMENT CONNECTION SHALL BE DESIGNED FOR 100% OF MOMENT CAPACITY AND 60% OF SHEAR CAPACITY FOR SECTION DEPTH 200MMAND ABOVE & 50% OFSHEAR CAPACITY FOR SECTION DEPTH LESS THAN 200MM OR FOR ACTUAL DESIGNFORCES WHICHEVER IS HIGHER.
17. SPLICES SHALL BE DESIGNED TO TRANSFER 1.05 TIMES FULL MEMBER SPLICED.
18. SPLICES IN ROOF PURLINS SHALL BE STAGGERED.
19. CUT OUTS IN FLOORING UPTO 300MM X 300MM OR 300 DIA.
20. ALL LIFTING BEAMS/MONORAILS/CRANE GIRDERS SHALL BE CLEARLY PAINTED INDICATING ITS LIFTING CAPACITY.
21. (+) INDICATES TENSION AND (-) INDICATES AXIAL COMPRESSION FORCES INMEMBERS.
22. COLUMN BASES SHALL BE GROUTED AS EARLY AS POSSIBLE AFTER ERECTIONAND PREFERABLY BEFORE BOLTING.
23. HOLDING DOWN BOLTS AT THE COLUMN BASES SHALL BE THROUGHLY TIGHTENEDTO DEVELOP FULL FIXITY OF BASE AND SHALL BE PROVIDED WITH LOCK NUTARRANGEMENT.
24. ALL BOLTED CONNECTION SHALL HAVE A MINIMUM OF 2 NO. M16 FOR OS BOLTS OR 2NO. M20 FOR HS BOLTS. ALL ARE TO BE LOCATED SYMMETRICALLY ABOUT THE WEB OR VERTICAL LEG OF CONNECTED MEMBER.
25. ALL WORK POINTS FOR BRACING MUST BE IN ACCORDANCE WITH WITH EIL DRAWINGS.
26. STRUCTURAL STEEL SURFACES SHALL BE PAINTED WITH PRIMER AS PER EILSPECIFICATION/COMPACTIBLE WITH FINAL ENVISAGE PAINT SPECIFICATION
27. ALL WELDS SHALL BE CONTINUOUS FILLET WELD UNO.

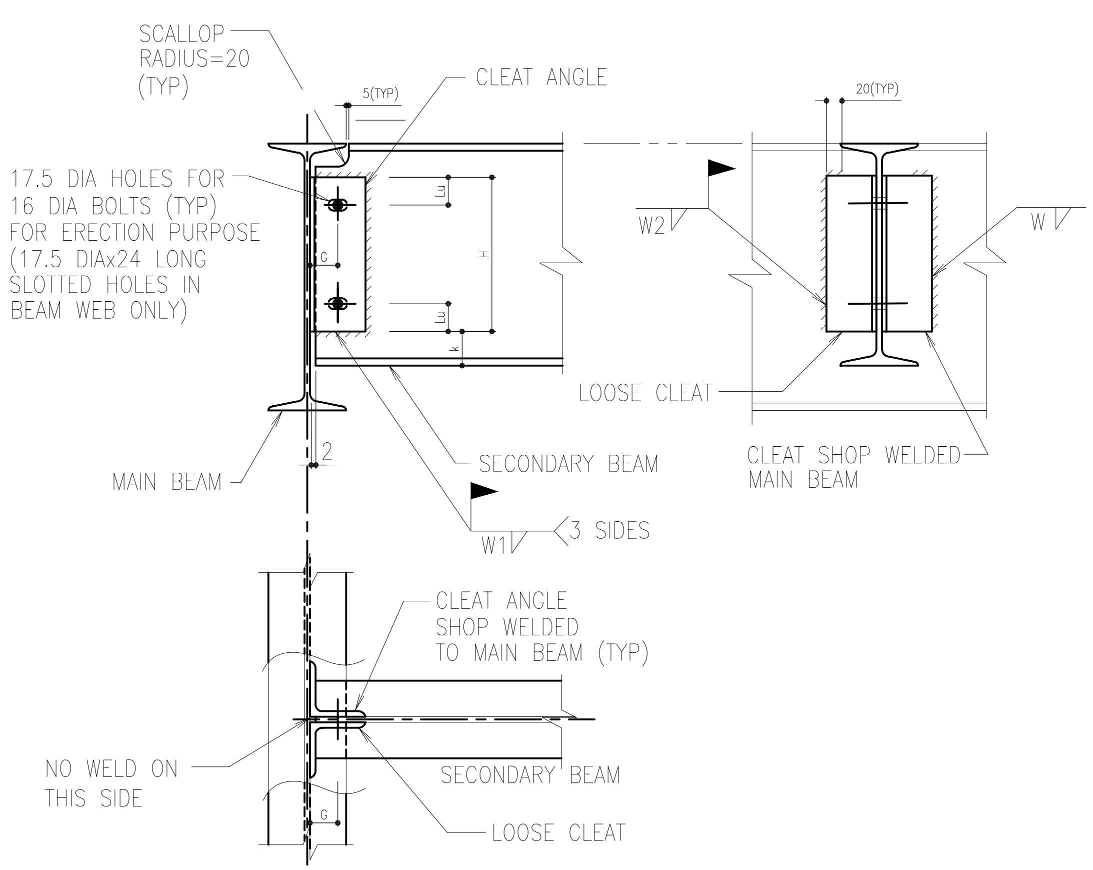
DATE			
BY	SMS	SMS	KMP
	DRAWN	DSGND	CHKD

L&T-CHIYODA LIMITED
BARODA

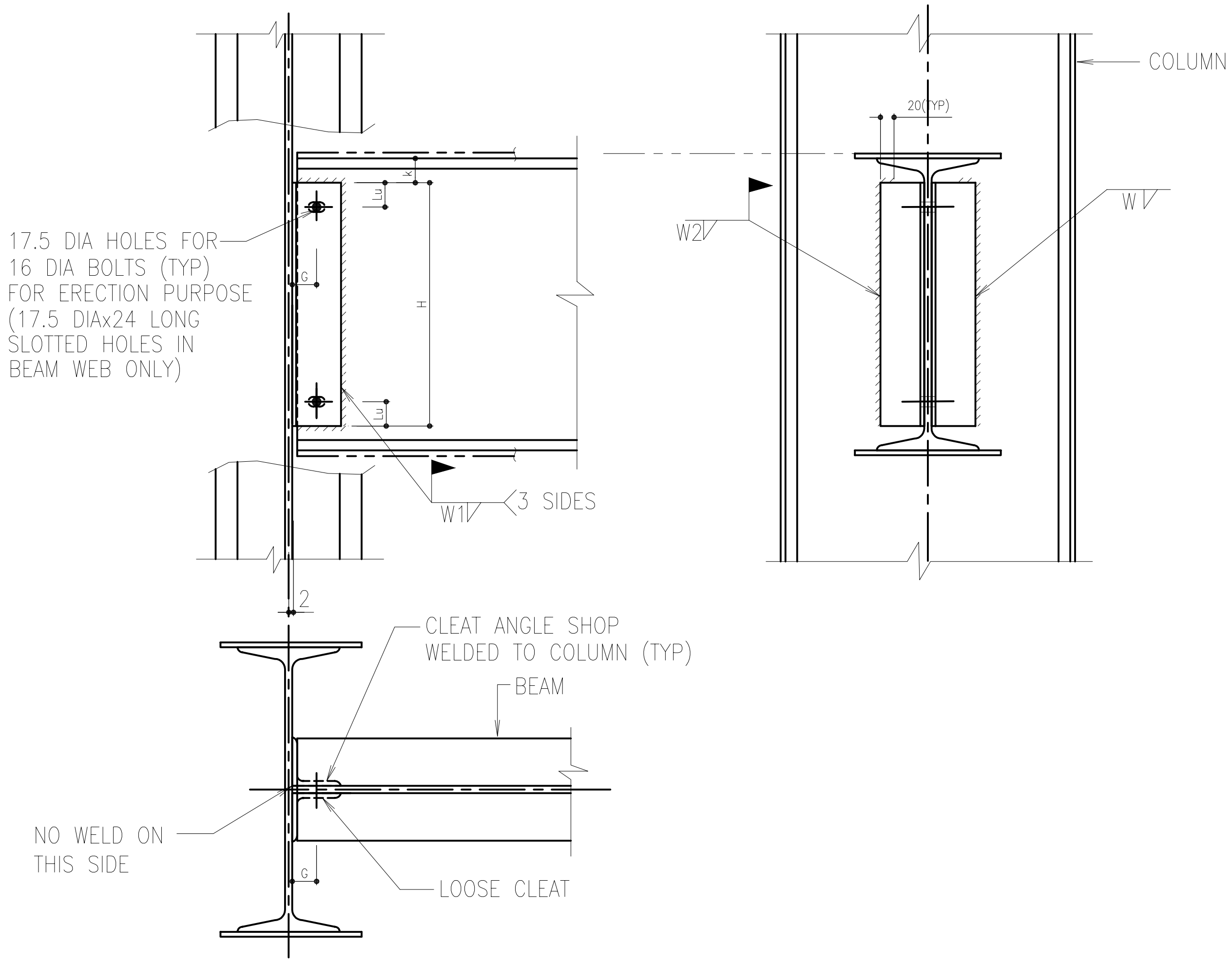
PROJECT
ANALYSIS & DESIGN OF PIPERACK SUPERSTRUCTURE

TITLE
BEAM MOMENT CONNECTION

SCALE		JOB NO.	
PROJECT	DRAWING NO.		REVISION
MP	MP/PR-1/ST/5		0



FOR ISMB SECTION



FOR ISMB SECTION

BEAM SIZE NOTE-5	CLEAT SIZE					WELD SIZE			ERECTION BOLTS NO-SIZE	SHEAR CAPACITY kN
	SECTION	H	k	Lu	G	W	W1	W2		
MB200	L75x75x8	105	35	25	40	6	8	8	2-M16	34
MB250	L75x75x8	150	40	25	40	6	8	8	2-M16	65
MB300	L75x75x8	200	40	25	40	6	8	8	2-M16	108
MB350	L75x75x8	250	42.5	25	40	8	8	8	2-M16	164
MB400	L90x90x8	295	45	25	50	8	8	8	2-M16	192
MB450	L90x90x8	345	47.5	35	50	8	8	8	4-M16	245
MB500	L90x90x8	390	50	35	50	8	8	8	4-M16	290
MB600	L100x100x10	485	57.5	40	60	8	8	10	4-M16	432

BEAM SIZE NOTE-5	CLEAT SIZE					WELD SIZE			ERECTION BOLTS NO-SIZE	SHEAR CAPACITY kN
	SECTION	H	k	Lu	G	W	W1	W2		
MB200	L75x75x8	130	35	25	40	6	8	8	2-M16	51
MB250	L75x75x8	170	40	25	40	6	8	8	2-M16	82
MB300	L75x75x8	220	40	25	40	6	8	8	2-M16	125
MB350	L75x75x8	265	42.5	25	40	8	8	8	2-M16	170
MB400	L90x90x8	310	45	25	50	8	8	8	2-M16	206
MB450	L90x90x8	355	47.5	35	50	8	8	8	4-M16	254
MB500	L90x90x8	400	50	35	50	8	8	8	4-M16	300
MB600	L100x100x10	485	57.5	40	60	8	8	10	4-M16	432

GENERAL NOTES

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DATE			
BY	SMS	SMS	KMP
	DRAWN	DSGND	CHKD

L&T-CHIYODA LIMITED
BARODA

PROJECT
ANALYSIS & DESIGN OF PIPERACK SUPERSTRUCTURE

TITLE
BEAM SHEAR CONNECTION

SCALE	JOB NO.	
PROJECT	DRAWING NO.	REVISION
MP	MP/PR-1/ST/6	0

F.1 GENERAL

In case of longitudinal direction frame, calculation of force coefficient depends on projected area of frame members and pipes. So it becomes essential to study effect of pipes on force coefficient. Here attempt is made to study, calculation of force coefficient using project specification, Indian standard (IS 875 – 1987) and ASCE guidelines for wind load on petrochemical facilities.

F.2 FORCE COEFFICIENT GIVEN BY PROJECT SPECIFICATION

Force coefficient provided in project specification is equal to 2.00 for width pipe rack with between 6 to 10 m

i.e k = 2.00

Therefore, Wind Force

$F = K.P_z.S\ N$

where,

P_z = Design wind pressure (kN/m^2) = 1.61 kN/m^2

S= Spacing of portals (m) = 8.00 m

N = number of nodes

k = Force coefficient for pipe rack (including wind load factor for pipe)

Width of Piperack	k
Upto 4 m	1.25
Above 4m upto 6m	1.50
Above 6m upto 10m	2.00
Above 10m upto 12m	2.50

F =k x Ps x S x N

=(2 x 1.61 x 8 x21) +(2 x 1.28 x 8 x 14)

F =827.68 kN

F.3 FORCE COEFFICIENT CALCULATION USIGN IS: 875-1987

F.3.1 Effective Area (A_{eff}) :-

F.3.1.1 Effective area for Frame

Member	Breadth (m)	Length (m)	Nos.	Area(m^2)
(1)	(2)	(3)	(4)	(5)=(2) x(3) x(4)
Cloumn-C1	0.30	5.00	7	10.50
Cloumn-C2	0.23	2.00	5	2.30
Cloumn-C3	0.23	2.00	5	2.30
Cloumn-C4	0.23	3.00	5	3.45
Cloumn-C5	0.23	1.50	5	1.73
Cloumn-C6	0.30	2.00	2	1.20
Cloumn-C7	0.30	3.00	2	1.80
Cloumn-C8	0.30	1.50	2	0.90
Beam-LB1	0.35	8.00	6	16.80
Beam-LB2	0.35	8.00	6	16.80
Beam-LB3	0.35	8.00	6	16.80
Beam-LB4	0.35	8.00	6	16.80
Beam-LB5	0.50	8.00	6	24.00
Ver. Bracing	0.27	5.00	8	10.80
Ver. Bracing	0.27	9.80	2	5.29
Portal	0.35	1.00	24	8.40
		Total Effective Area		139.87

Total Area

A_{total} = (W+C) x H

= (48+0.62) x 13.5

= 656.37 m^2

Solidity Ratio,

$\phi = A_{eff}/A_{total}$

= 0.213

Force Coefficient (for single frame)

Cf = 1.79 (Cl: 6.3.3.3, Table 28)

Frame Spacing

S = 8.0 m

Least overall Frame Dimension

D_{min} = 8.0 m

Frame Spacing Ratio, S.R.

S.R = S/D_{min} = 1

Number of Frames

n = 2

Effective Solidity Ratio,

$\beta = \phi$ [Cl:6.3.3.4 (b)]

Shielding Factor

$\eta = 0.887$ [Cl: 6.3.3.3, Table 29]

Total Force Coeff, $C_{f,total}$ = Cf x (1+(n-1) x η)

= 3.37

For Succeeding Frames, $C_{f,s}$ = C_f x η = 1.58

F.2.1.1 Effective area for Pipes

Effective Area = (Dia of Largest pipe x Length of pipe)

Force coeff. For pipe = 0.7

Largest pipe Diameter = 700 mm

Length of pipe per tier = 48 m

Level	Dia of largest pipe (inch)	Length m	Area m^2
EL 105 m	0.70	48.00	33.60
EL 107 m	0.70	48.00	33.60
EL 109 m	0.70	48.00	33.60
EL 112 m	0.70	48.00	33.60
		Total	134.40

F.3.1.3 Total Wind force calculation

a) For Frame

F_{frame} = A x Pz x Cf
=(85.12 x 1.61 x 3.37) + (54.75 x 1.28 x 3.37)
= 698.00kN

Where,

Eff Area of frame upto 10 m Height
= 85.12m^2

Eff Areaof frame above 10 m Height
= 54.75m^2

b) For Pipe

F_{pipe} = A x Pz x Cf
= (0.7x 8 x 6 x 1.61 x 0.7 x 3) + (0.7 x 8 x 6 x 1.28 x 0.7 x 1)
= 143.71kN

Total Force = 841.71kN

Therefore K Factor according IS code

k x Pz x S x Number od f nodes = 841.71

$$k = \frac{841.71}{(1.61 \times 8 \times 21 + 1.28 \times 14 \times 8)}$$

k = 2.03

F.4 FORCE COEFFICIENT CALCULATION USIGN ASCE GUIDELINES

F.4.1 Effective Area (A_{eff}) :-

F.4.1.1 Effective area for Frame

Effective area will be same as calculated in section F.2.1.1

i.e. Effective Area A_{eff} = 139.87 m^2

F.4.1.1 Effective area for Pipes

Effective Area A_{eff} = (Diameter of Largest pipe + 10 % width of pipe rack) x Length of pipes

Force Coeff for Pipe = 0.7
Length of Pipe bet^n bents = 8m
Width of pipe rack = 8m
Wind Force (F) :-

Level	Dia of largest pipe (inch)	Projected Area ft^2/ft	Projected Area m^2/m	Force Coeff	Pz (kN/m^2)	Force (kN)
EL 105 m	20	4.66	1.42	0.7	1.16	9.23
EL 107 m	10	2.63	0.80	0.7	1.16	5.20
EL 109 m	28	6.29	1.92	0.7	1.16	12.45
EL 112 m	10	2.63	0.80	0.7	1.28	5.74
EL 113.5 m	99.97	20.91	6.38	0.7	1.28	45.70

F.4.1.3 Total Wind force calculation

a) For Frame

F_{frame} = A x Pz x Cf
=(85.12 x 1.61 x 3.37) + (54.75 x 1.28 x 3.37)
= 698.00kN

Where,

Eff Area of frame upto 10 m Height
= $85.12 m^2$

Eff Areaof frame above 10 m Height
= $54.75 m^2$

b) For Pipe

F_{pipe} = A x Pz x Cf
= 78.33kN

Total Force = 776.33kN

Therefore K Factor according ASCE Guidelines

k x Pz x S x Number od f nodes = 776.33

$$k = \frac{776.33}{(1.61 \times 8 \times 21 + 1.28 \times 14 \times 8)}$$

k = 1.88

Discussion: -

From above study it can be concluded that, force coefficient given by project specification (k= 2.00) is on conservative side according to ASCE (k=1.88) guidelines and according to Indian standards (IS 875 – 1987) (k=2.03) is in acceptable limit.

1. “Analysis and Design of Steel Pipe Rack Superstructure” by Sagar M Sonawane. Advances in Steel Structures, S. V National Institute of Technology, Surat, 8^{th} & 9^{th} February 2007.