1. PURPOSE AND SCOPE

The scope of this document is to provide the calculations for the Analysis and Design of Steel Shelter.

The software used for structural analysis and design is STAAD Pro Connect Edition
.
A three-dimensional model of shelter structure is created in STAAD and all relevant loads are applied in accordance with ASCE 7-10 and member design is performed according to **AISC-360-10**.

In detailed design phase, appropriate design and detailing considerations as per AISC 341 shall be considered as necessary.

This document covers only sizing of primary steel members. The design of connections and sizing of secondary & tertiary steel members shall be performed in the detailed design phase.

2. REQUIRED REFERENCES

This section lists the practices, codes, standards, specifications, and publications that shall be used with this document. Unless otherwise specified herein, use the latest edition.

3. PROCESS INDUSTRY PRACTICES

PIP	Description
PIP STC01015	Structural Design Criteria

4. INTERNATIONAL CODES

CODES	Description
ASCE 7-10	Minimum Design Loads for Buildings and Other Structures
AISC 360-10	Specification for Structural Steel Buildings
AISC 341-10	Seismic Provisions for Structural Steel Buildings

5. REFERENCE LITERATURES

Reference Literature/	Design Guide Title
ASCE 41180	Wind Loads for Petrochemical and Other Industrial Facilities
ASCE 40262	Wind Loads and Anchor Bolt Design for Petrochemical Facilities

6. MATERIALS

All materials and structural steel components shall be in accordance with project specification "Design Specification for Steel Structures".

Constant	Value
W-shapes, WT-shapes	ASTM A992/A992M
Yield strength, (F_y in MPa)	345
S-shapes, Channels, Angles	ASTM A36/36M
Yield strength, (F_y in MPa)	250
Elastic Modulus	E = 210,000 MPa
Density	7850 kg/m^3
Poisson's Ratio	ν = 0.3
Co-efficient of Thermal Expansion	$\alpha = 12 \times 10^{-6}$ m/m ℃

7. STRUCTURE DESCRIPTION

The Geometry of Off-gas Compressor Shelter is considered as per General Plot Plan Layout The dimension as below;

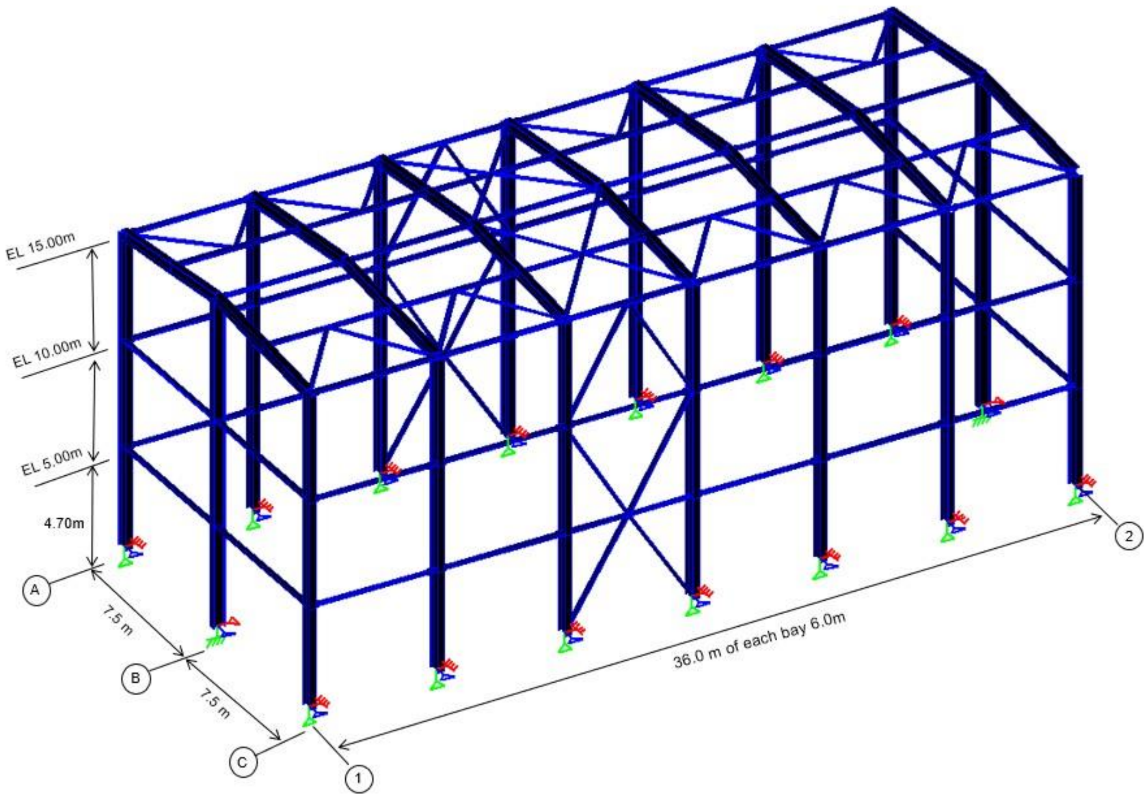
- Width of the structure is 15.00m;
- Length is 36.0m;
- Frame spacing is 6.0m;
- Eave height 15.00m
- Roof Slope is 1 in 10.

The shelter structure is enclosed with sheeting on all sides, except 3.0m opening above FGL. Shelter is considered to be supported on concrete pedestal of height 0.3 m from the ground.

Shelter consists of:

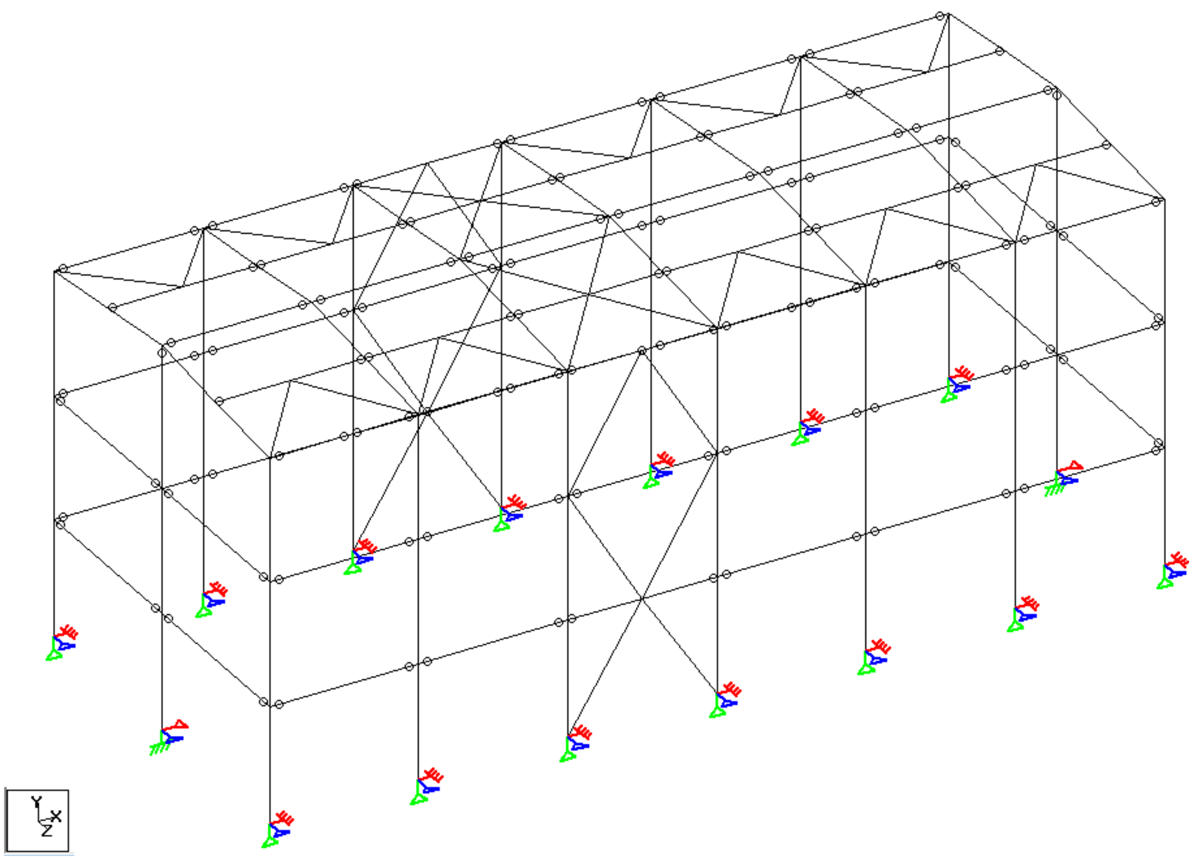
- Gantry girder supporting 8 MT rated capacity crane.

Moment resisting frames in transverse direction, braced framing in longitudinal direction. Column Base supports are fixed in transverse direction & pinned in longitudinal direction.



3D View of Shelter-01

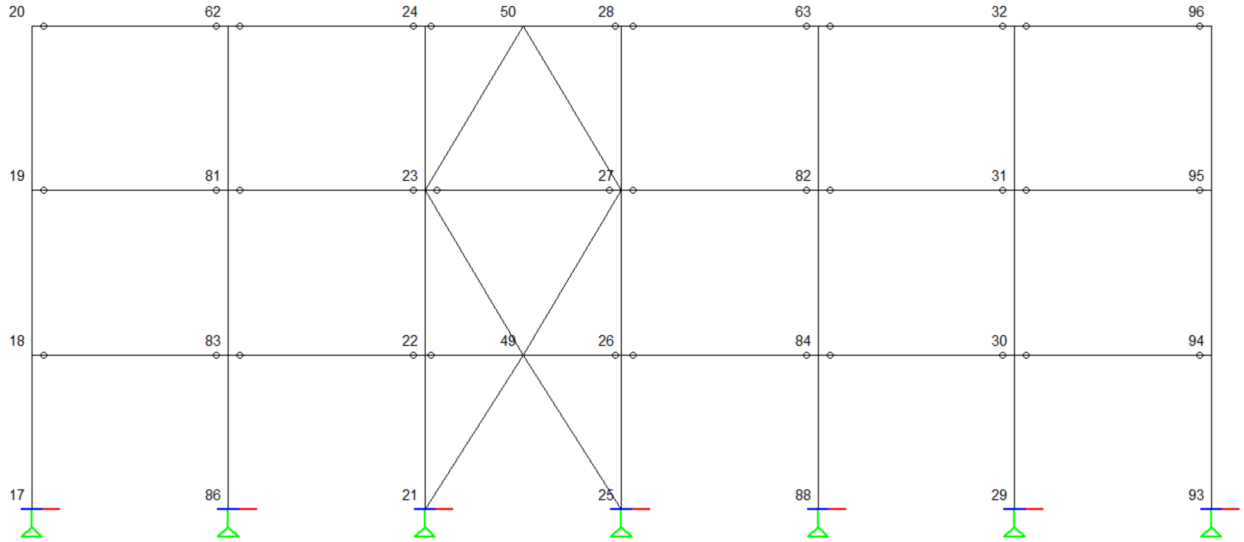
8. STAAD MODEL



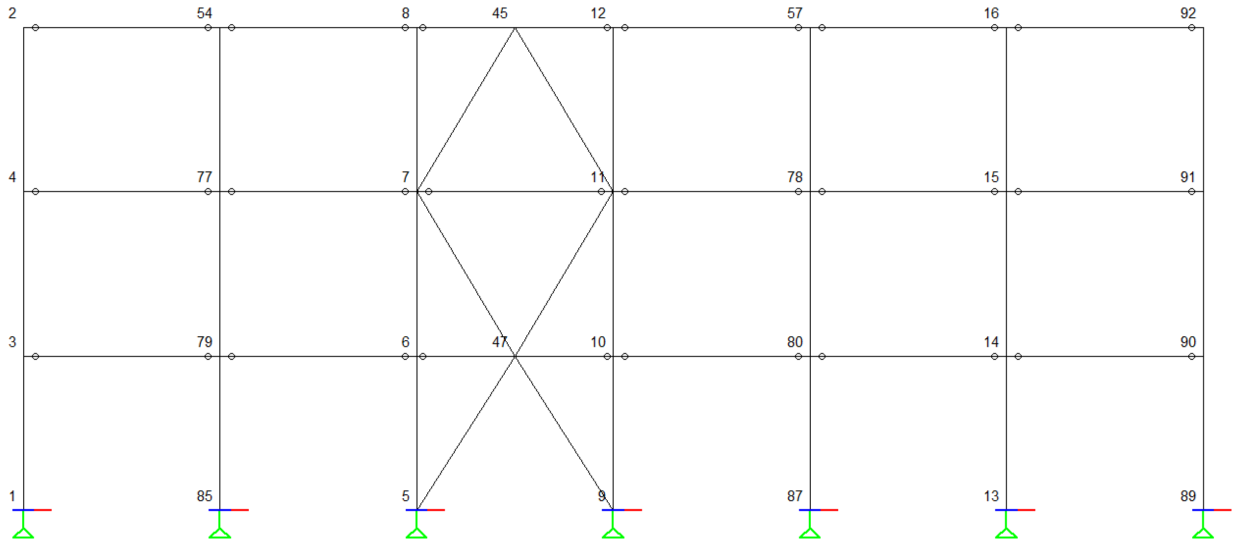
Note:
Braces are considered as TRUSS members (pure Axial) in STAAD which is same as members with end moment releases.

Figure 4-2 Isometric View of Shelter with releases & support

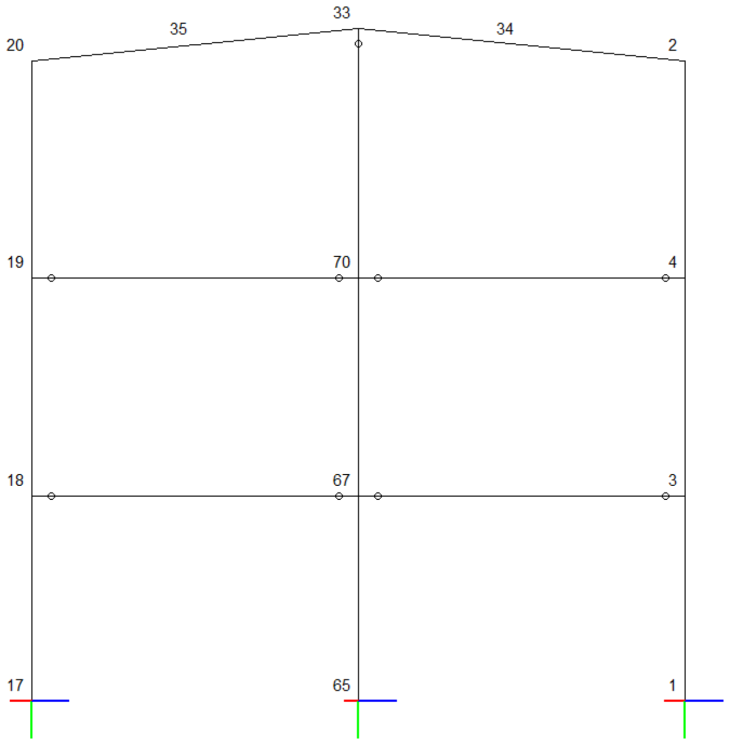
9. NODE NUMBER



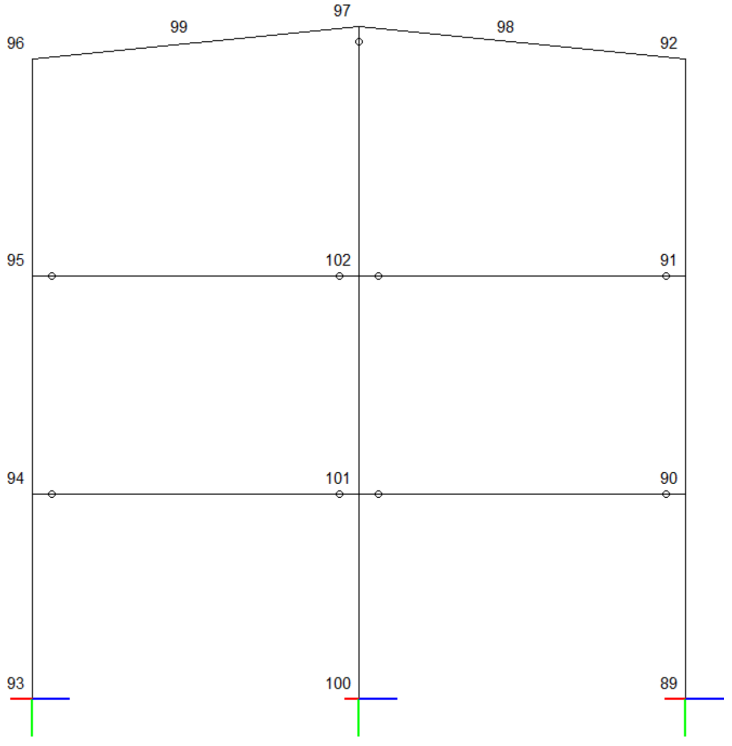
Node number along Grid A



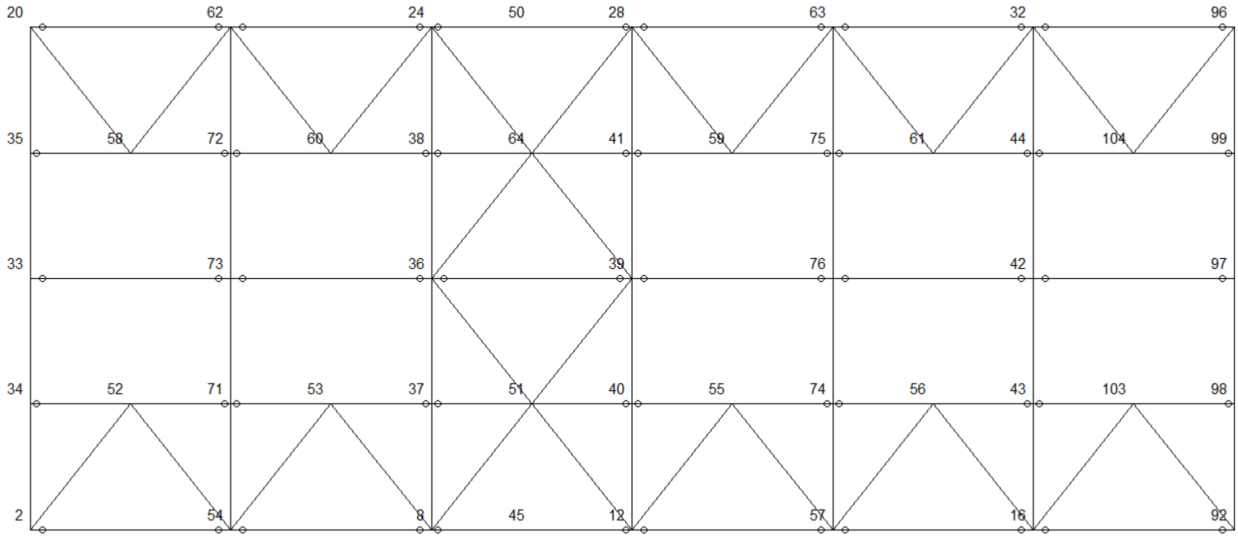
Node number along Grid C



Node number along Grid 1



Node number along Grid 2



Node number – Roof Plan View

10. MEMBER PROPERTY

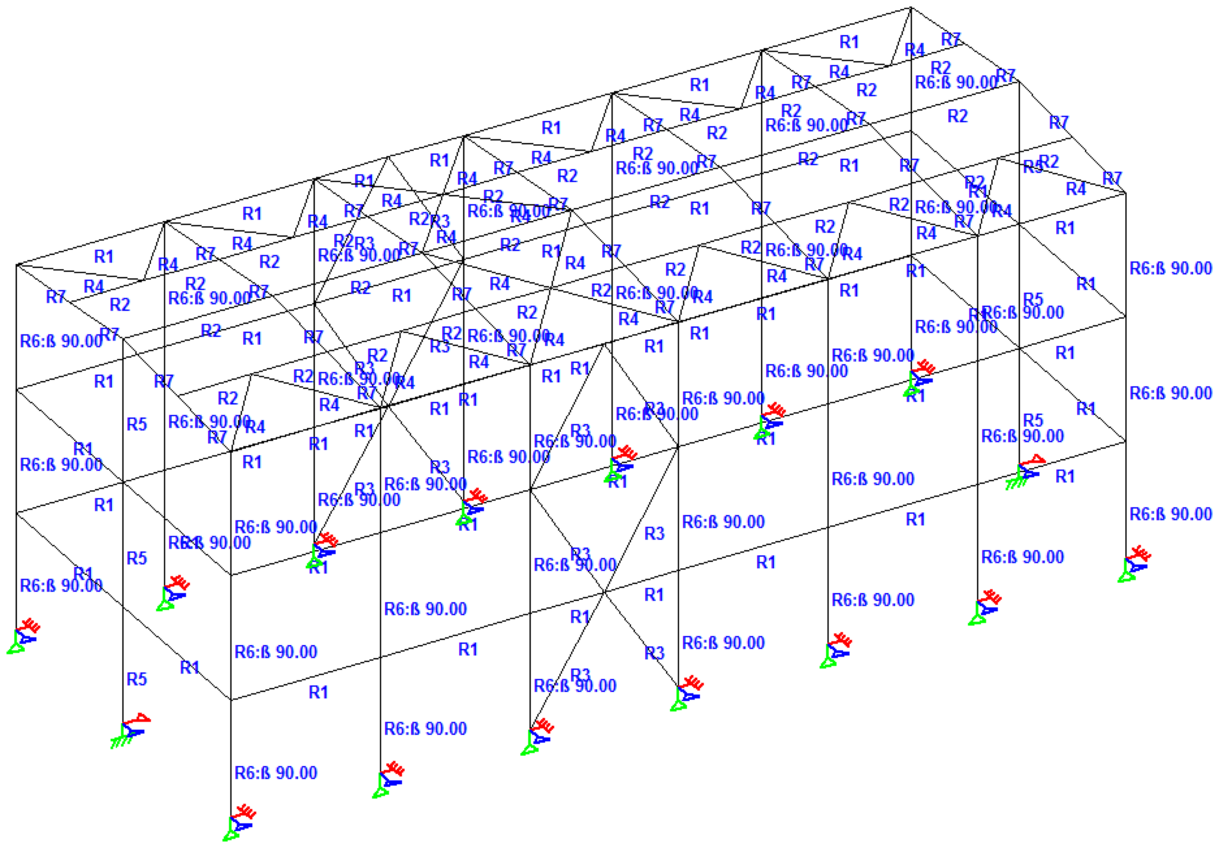


Figure Isometric View of Member Number

SL. No	Member No	Members
1	R1	HE160A
2	R2	HE160A
3	R3	L120X120X12 SD
4	R4	L90X90X10 SD
5	R5	HE500A
6	R6	HE600B
7	R7	HE450A

11. LOADS & LOAD COMBINATIONS

Load case No.	Load case	Loads
1	DS	DEAD LOAD (DS)
2	L1	LIVE LOAD(L1)
3	L2	CRANE IMPACT LOAD (L2)
4	LR	ROOF LIVE LOAD (LR)
5	WX1(+)	WIND LOAD (WX (+) CASE A Cpi = -0.18)
6	WX2(+)	WIND LOAD (WX (+) CASE B Cpi = 0.18)
7	WX1(-)	WIND LOAD (WX (-) CASE A Cpi = -0.18)
8	WX2(-)	WIND LOAD (WX (-) CASE B Cpi = 0.18)
9	WZ1(+)	WIND LOAD (WZ (+) CASE A Cpi = -0.18)
10	WZ2(+)	WIND LOAD (WZ (+) CASE B Cpi = 0.18)
11	WZ1(-)	WIND LOAD (WZ (-) CASE A Cpi = -0.18)
12	WZ2(-)	WIND LOAD (WZ (-) CASE B Cpi = 0.18)
13	EX	SEISMIC LOAD (EX)
14	EZ	SEISMIC LOAD (EZ)
15	EY	SEISMIC LOAD (EY)
16	TS1	SUSTAINED THERMAL LOAD (TS MAX)
17	TS2	SUSTAINED THERMAL LOAD (TS MIN)

Table Primary Load case

12. DEAD LOAD (DS)

Structural self-weight of modelled steel members is automatically generated in STAAD.

Structural self-weight of all steel members is calculated with a unit weight of steel as 78.5kN/m^3 multiplied by a contingency factor of 1.2 to account for connection details

Fire proofing to the structural members (column, beams & vertical bracing) is considered upto elevation 10 m. The 50mm thick concrete fireproofing is considered in accordance with “Passive Fire Protection Technical Specification. The fireproof weight is calculated automatically in STAAD.

Dead Load On Roof

Self-weight of roof/wall sheet (assumed)	=	6.00	kg/m^2
	=	0.06	kN/m^2
Self-weight of purlin and girts (UPN 200)	=	25.3	kg/m
	=	0.25	kN/m
Assuming purlins are located at every 1.0m spacing			
Area load due to purlin	=	0.25	kN/m^2
Total dead load for sheeting	=	0.25+0.06	
	=	0.313	kN/m^2
Considering 20% contingency for connections			
Design dead load for sheeting	=	0.38	kN/m^2

ROOF AREA

Contributing span (m)	Unit load (kN/m^2)	Sheet load including Purlin weight (kN/m)
3	0.38	1.14
6	0.38	2.28

SIDE WALL

Contributing span (m)	Unit load (kN/m^2)	Side sheeting load including Side runner (kN/m)
3	0.38	1.14
6	0.38	2.28
3.75	0.38	1.43
7.5	0.38	2.85

The Dead load of 2.5 kN/m shall be applied on longitudinal roof beams to account for roof ridge ventilation members.

Dead Load - Gantry Girder

Self weight of crane gantry girder

Self weight of supporting bracket beam

Gantry Girder			Supporting Bracket Beam			Total Force		
Contributing span (m)	Unit load (kN/m)	Selfweight of crane gantry girder (kN)	Contributing span (m)	Unit load (kN/m)	Selfweight of Bracket Beam (kN)	TOTAL Dead load, (kN)	Lever Arm (m)	Moment (kNm)
3	1.18	3.54	1	1.25	1.25	**4.79**	1	**4.79**
6	1.18	7.08	1	1.25	1.25	**8.33**	1	**8.33**

Crane Dead Load (CD)

Crane load is considered 8T lifting capacity (Assumed).

For the overall structural design, the critical crane load calculated is applied on all the frames. The Crane Loads are applied at EL (+)12.00m.

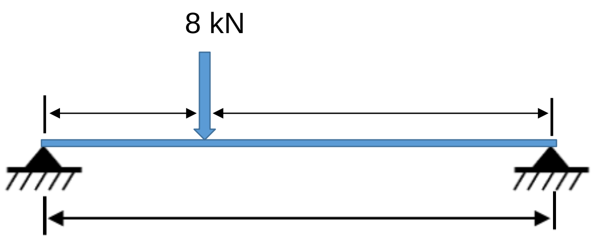
Design Load calculation is as follows.

Rated load capacity of crane W = 8000 kg = 80 kN
Span of crane = 15.00 m
Weight of crane bridge (INCLUDED OTHER WEIGHTS) Wc
= 4000 kg = 40 kN
Weight of hoist and trolley Wt = 800 kg = 8 kN
No of wheel on each side = 2
No's
Wheel base = 3.15 m
Distance of the hook from grid-1 = 1 m
Distance of the hook from grid-3

Primary Load cases due to Crane operation:
= 1 m
Dead (CD) = vertical dead load of the crane + trolley weight

1) Wheel load due to crane bridge
(Crane bridge load / 2) / No. of Wheel on one side = (40 / 2) / 2
= 10 kN

2) Wheel load due to hoist and trolley



a) When hook is near grid –A

Wheel load on grid -A = 3.73 kN = (8 x 14 / 15) / 2

Wheel load on grid -C = 0.27 kN = (8 x 1 / 15) / 2

Wheel Load	Bridge Load kN	Trolley Load kN	Dead (CD) = Bridge Load + Trolley Load kN
Wheel load along grid A	10.00	3.73	13.73
Wheel load along grid C	10.00	0.27	10.27

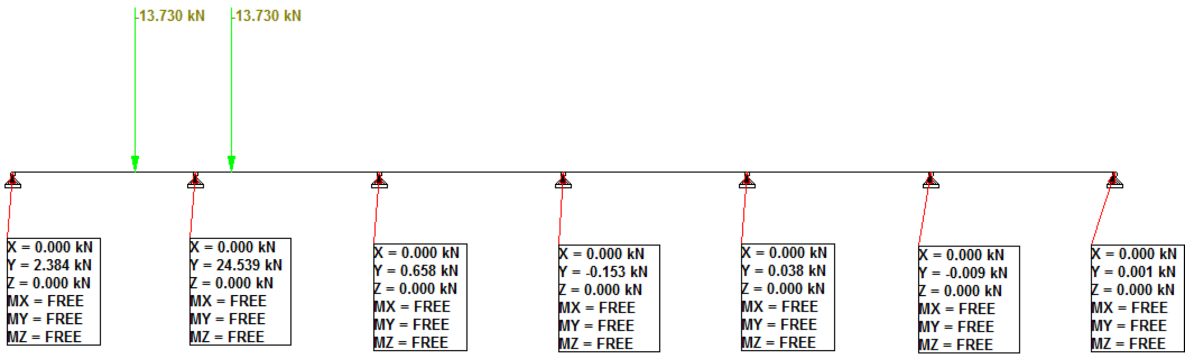


Figure Crane-Dead Load Max Staad reaction on Grid A column support

- Maximum Wheel load = 24.540 kN (applied in staad for all gantry support columns)
- Moment due to gantry supporting beam = 1m; 24.54 x 1m =24.540 kNm

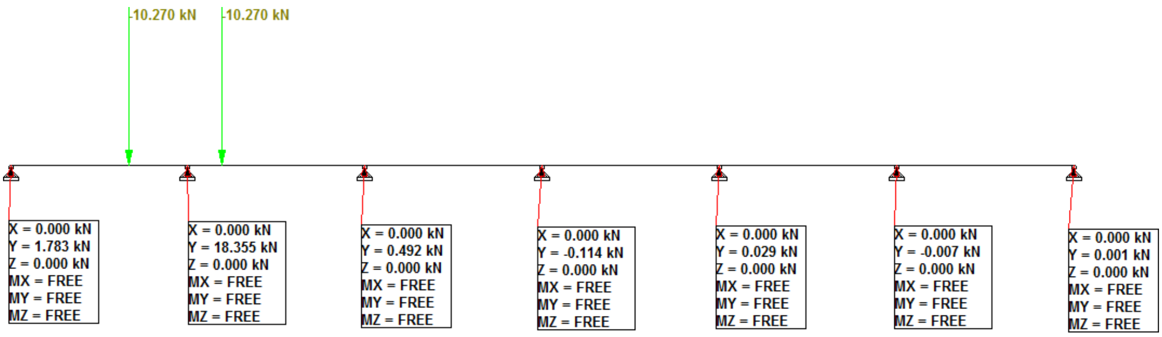
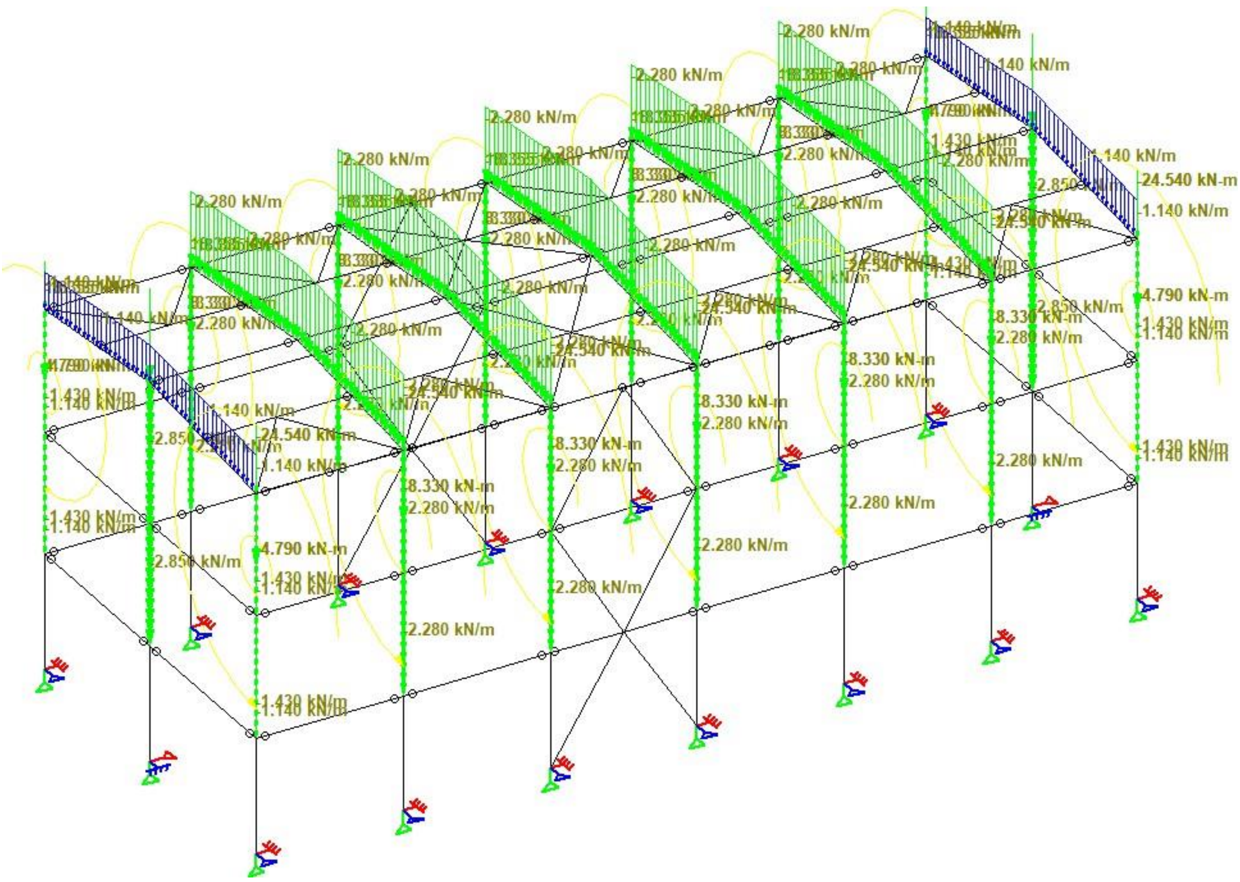


Figure Crane-Dead Load Max Staad reaction on Grid C column support

- Maximum Wheel load = 18.355 kN (applied in staad for all gantry support columns)
- Moment due to gantry supporting beam = 1m; 18.355 x 1m = 18.355 kNm



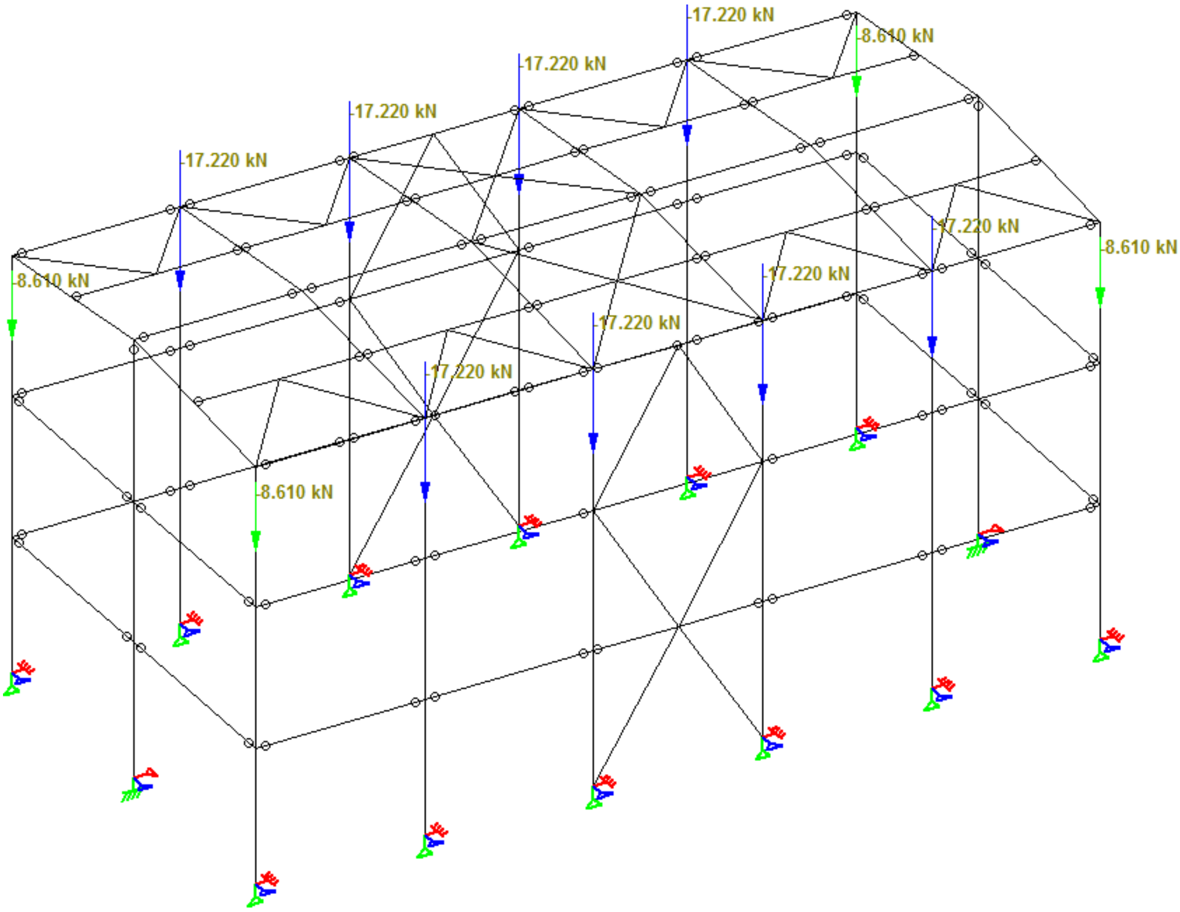
Dead Load (DS)

13. LIVE LOAD (L1)

The Walk way of width 1.0m is assumed for crane accessibility at EL (+)12.00m. The live Load is considered as 2.87kN/m² (Section 4.1.3 of PIP STC01015).

Platform LL	=	2.87	kN/m^2
Width	=	1	m

Contributing span (m)	Unit Load (kN/m^2)	Live Load on Platform (kN)
3	2.87	8.61
6	2.87	17.22

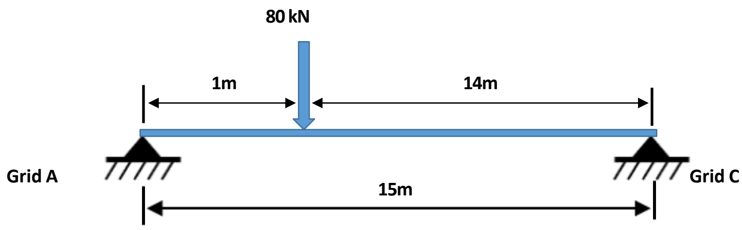


Live Load (L1)

14. CRANE IMPACT LOAD (L2)

CRANE OPERATING (CO)

Wheel load due to Rated load Capacity	**=**	**80**	**Kn**

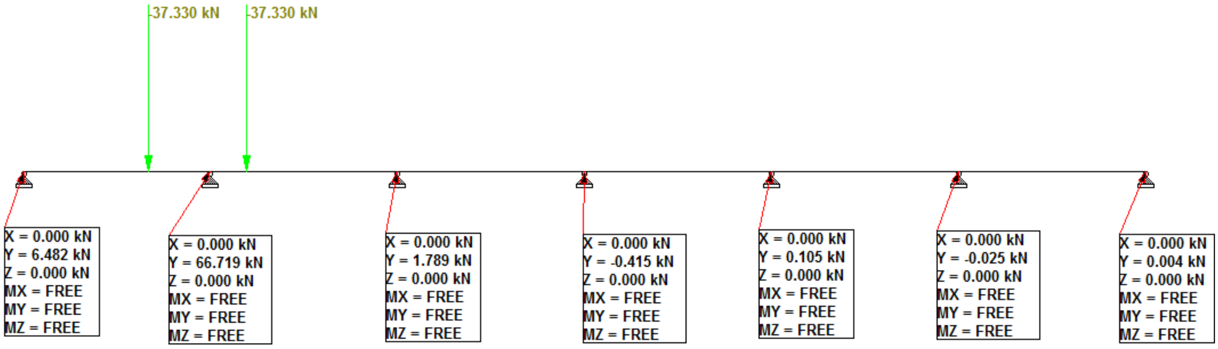


When hook is near grid –A

Wheel load on grid -A = (80 x 14 / 15) / 2 = 37.33 kN

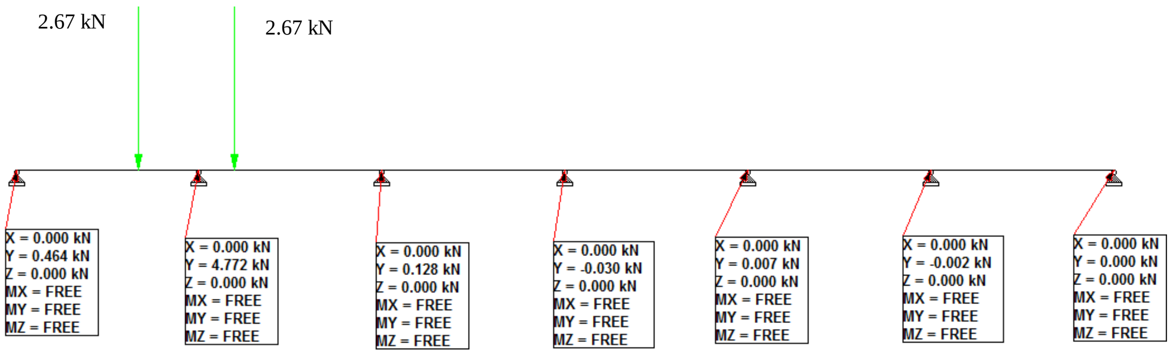
Wheel load on grid -C = (80 x 1 / 15) / 2 = 2.67 kN

Wheel Load	Crane Operating (CO) kN
Wheel load along grid A	37.33
Wheel load along grid C	2.67



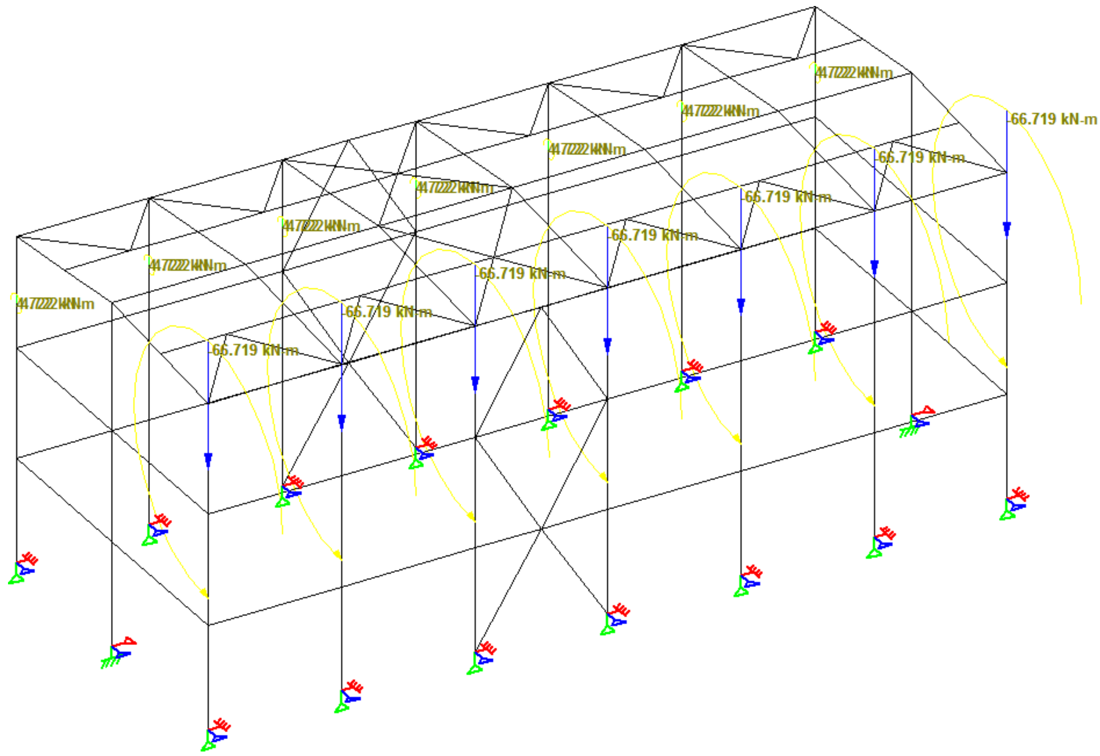
Crane-Operating Load Max reaction on Grid A column support

- Maximum wheel load = 66.719 kN (applied in staad for all gantry support columns)
- Moment due to gantry supporting beam = 1m; 66.719 x 1m =66.719 kNm



Crane-Operating Load Max reaction on Grid C column support

- Maximum wheel load = 4.772 kN (applied in staad for all gantry support columns)
- Moment due to gantry supporting beam = 1m; 4.772 x 1m =4.772 kNm



Structural Crane Operating Load (CO)

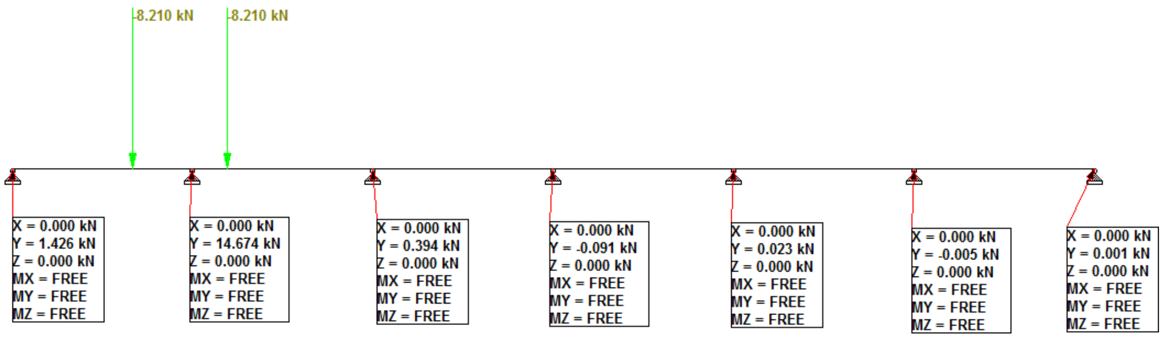
15. CRANE TRANSVERSE (CT)

As per ASCE 7-10, refer 4.9

Transverse (CT) = side thrust (transversal Impact load)

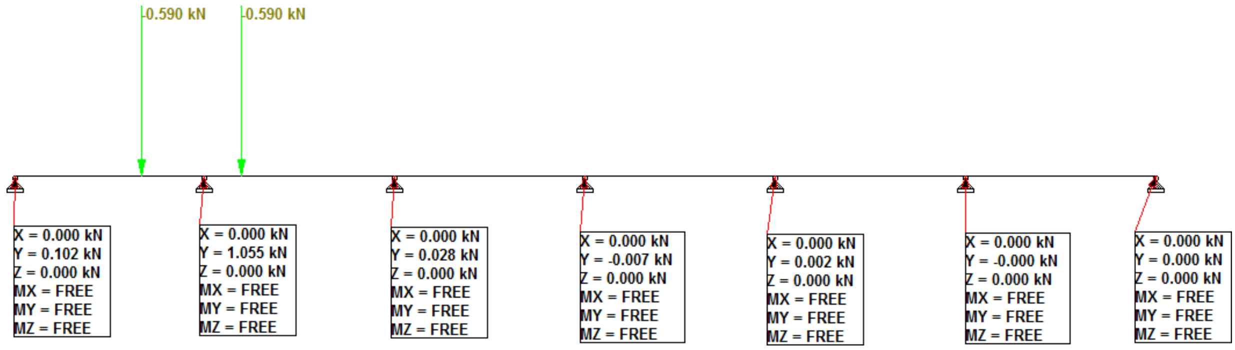
= 20% of the rated load capacity of the crane and the weight of the hoist and trolley (as per cl 4.9.4 of ASCE 7-10)

Wheel Load	Trolley Load	Crane Operating (CO)	Crane Transverse (CT) = 0.20*(trolley load+CO) kN
Wheel load along grid A	3.73	37.33	8.21
Wheel load along grid C	0.27	2.67	0.59



Crane-Side Thrust Load Max reaction on Grid A column support

Maximum wheel load = 14.674 kN (applied in staad laterally for all gantry support columns)



Crane-Side Thrust Load Max reaction on Grid C column support

Maximum wheel load = 1.055 kN (applied in staad laterally for all gantry support columns)

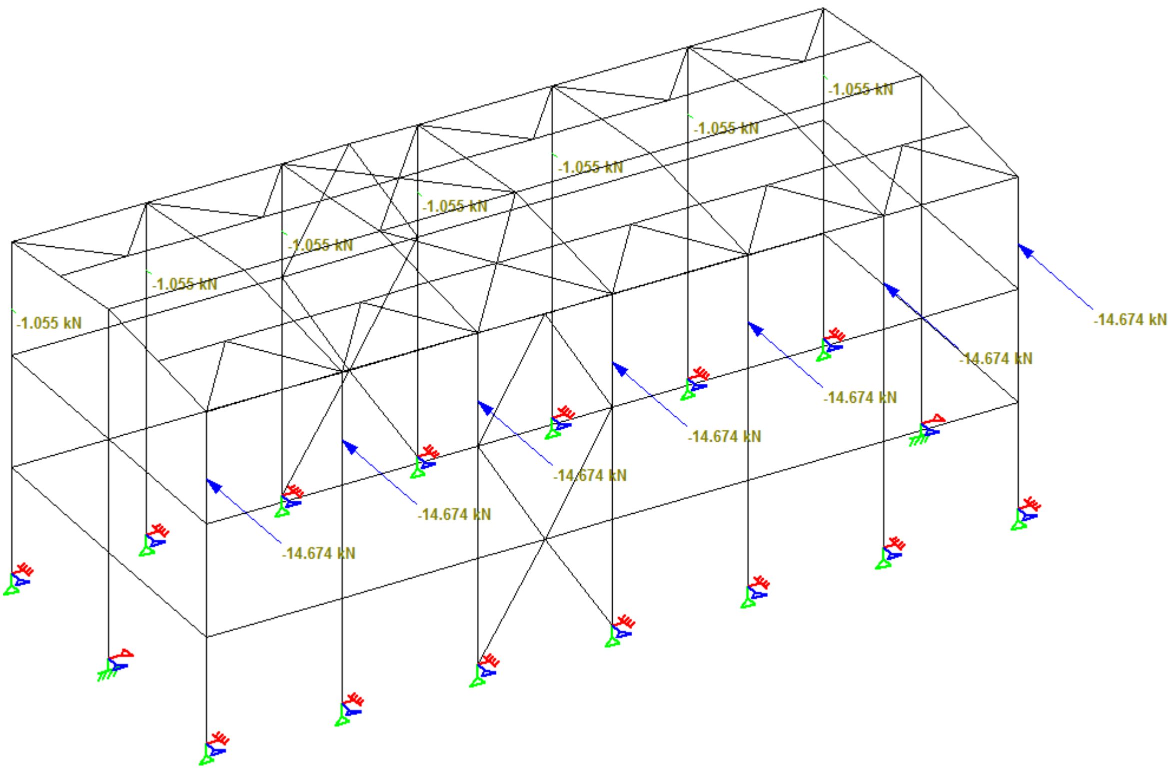


Figure 5-10 Structural Crane Side Thrust Load (CT)

16. CRANE LONGITUDINAL (CL)

As per ASCE 7-10, refer 4.9

Longitudinal (CL) = longitudinal traction (longitudinal Impact load)

= 10% of the maximum wheel load (= 0.1*(CD+CO)) (as per cl 4.9.5 of ASCE 7-10)

Wheel Load	Crane Dead (CD)	Crane Operating (CO)	Crane Longitudinal (CL) = 0.10*(CD+CO) *No. of wheels on each side
Wheel load along grid A	13.73	37.33	5.1
Wheel load along grid C	10.27	2.67	1.29

Maximum reaction on Grid A = 10.21 kN (applied in staad longitudinally for critical support columns)
Maximum reaction on Grid C = 2.59 kN (applied in staad longitudinally for critical support columns)

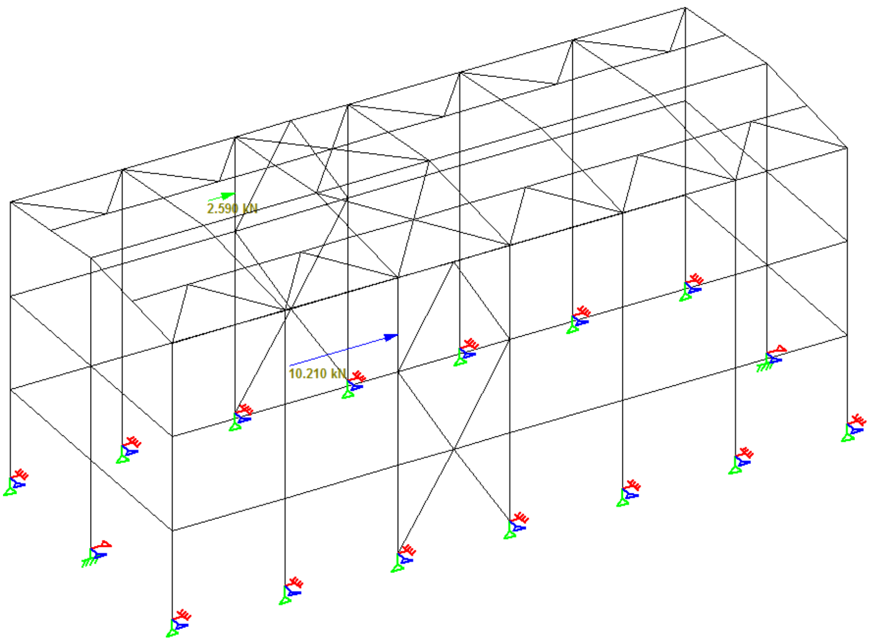


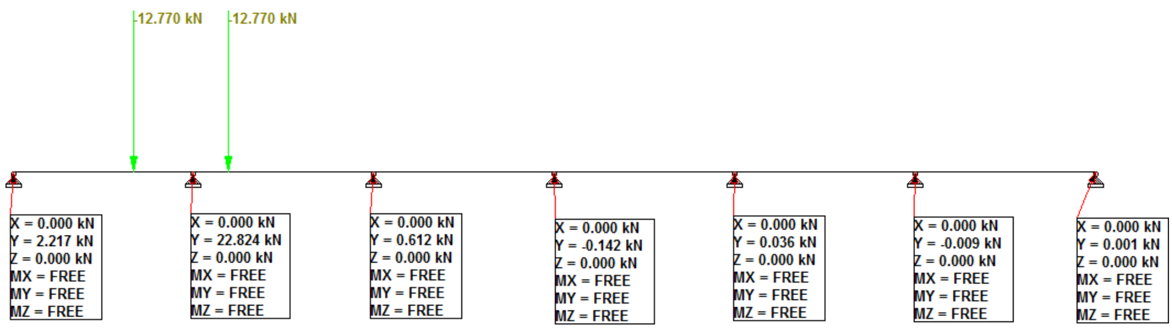
Figure 5-11 Structural Crane Longitudinal Load (CL)

17. CRANE IMPACT (CI)

As per ASCE 7-10, refer 4.9

Impact (CI)	=	vertical impact
	=	25% of the maximum vertical wheel load (= 0.25*(CD+CO)) (as per cl 4.9.3 of ASCE 7-10)

Wheel Load	Crane Dead (CD)	Crane Operating (CO)	Crane Longitudinal (CL) = 0.20*(CD+CO)
Wheel load along grid-A	13.73	37.33	12.77
Wheel load along grid-C	10.26	2.67	3.23



Crane-Impact Load Max reaction on Grid 1 column support

- Maximum wheel load = 5.773 kN (applied in staad for all gantry support columns)
- Moment due to gantry supporting beam = 1m; 5.773 x 1m = 5.773 kNm

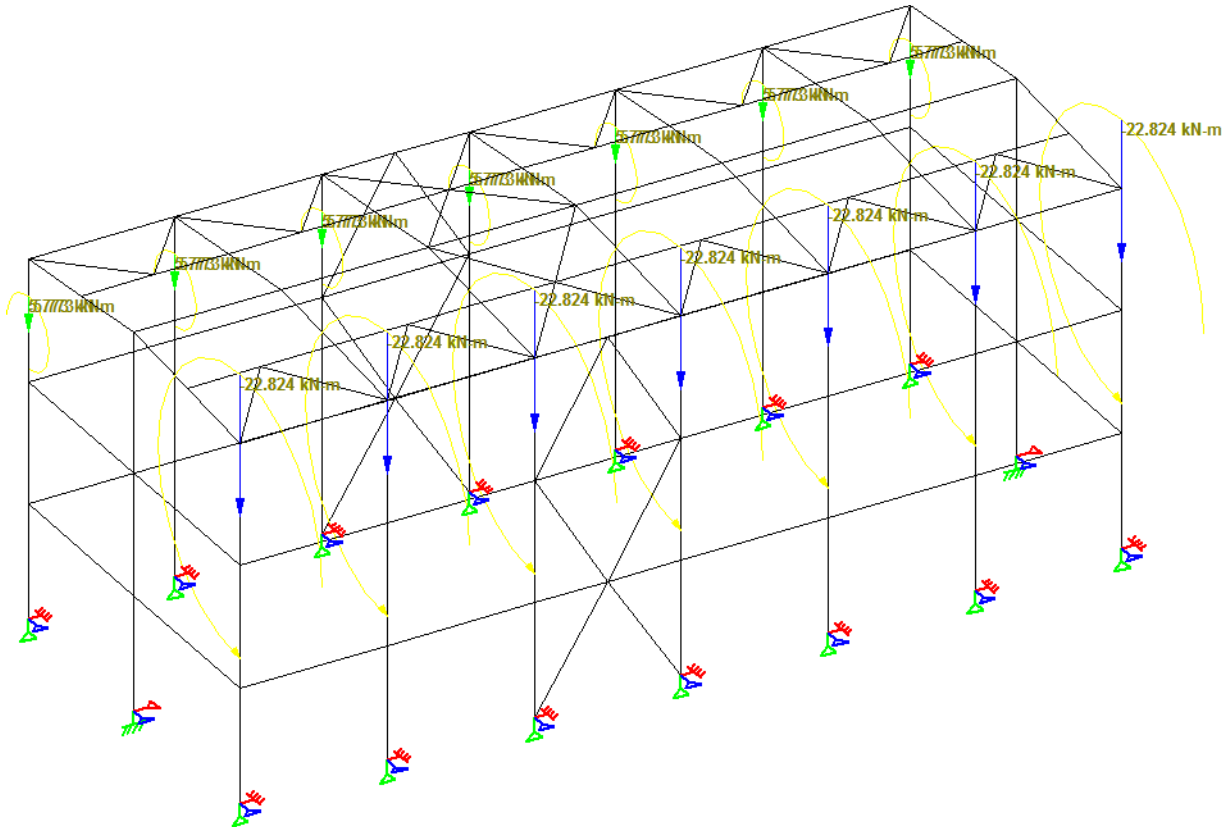


Figure 5-14 Structural Crane Impact Load (CI)

18. ROOF LIVE LOAD (LR)

Live load on Roof is considered as 0.96 kN/m2 (Refer Table 4.1, ASCE 7-10). Load is applied as UDL on the supporting main beams. The roof live load is reduced as per Section 4.8.2 of ASCE 7-10.

$$L_r = L_o R_1 R_2 \quad \text{where} \quad 0.58 \le L_r \le 0.96$$

A_T – Tributary area = 6*15 = 90 m^2

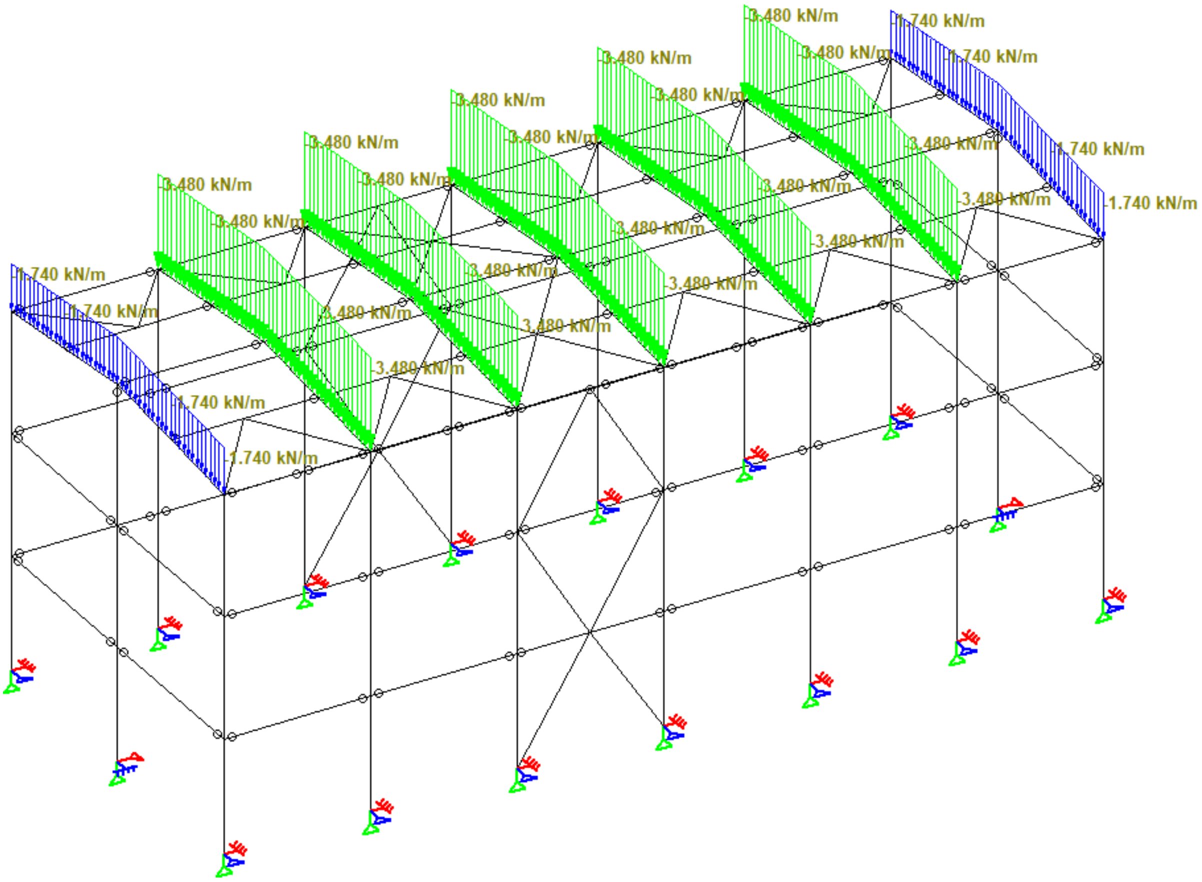
F – 0.12 * slope (in %) = 0.12*10 = 1.2

$R_1 = 0.6$ ($A_T > 55.74\ m^2$)

$R_2 = 1$ ($F < 4$)

Lr = 0.96*0.6 = 0.58 kN/m^2

Contributing span (m)	Unit Load (kN/m^2)	Live Load on Roof (kN/m)
3	0.58	1.74
6	0.58	3.48



Roof Live Load (LR)

19. WIND LOAD (WLX & WLZ)

Wind Parameters:

Structure Risk Category = III
(3sec-gust) = 85.70 m/s
(Return Period - 1700 years is considered for risk category III structures)
F, applied wind force = q_z G C_f A_f (Eq. 29.5-1), ASCE 7-10 q_z - Velocity Pressure at height z above Ground.
G - Gust effect factor
C_f - Net force coefficient
A_f - Projected area normal to wind

Velocity Pressure q_z:
q_z, (N/m2) = 0.613 Kz Kzt Kd V^2 (Eq. 27.3-1), ASCE 7 -10
K_z, Velocity pressure exposure coefficient K_{zt}, Topographic factor
K_d, Wind directionality factor
V, Basic wind speed (3 sec - Gust) m/s K_z, Velocity pressure exposure coefficient

Height		Exposure		
m	ft	C	D	D normalized to 1.0 at 33 ft
4.57	15	0.85	1.03	0.87
6.10	20	0.9	1.08	0.92
7.62	25	0.94	1.12	0.95
9.14	30	0.98	1.16	0.98
12.19	40	1.04	1.22	1.03
15.24	50	1.09	1.27	1.08
18.29	60	1.13	1.31	1.11
21.34	70	1.17	1.34	1.14
24.38	80	1.21	1.38	1.17

Exposure Factor = D

Provided wind speed is representative of the Exposure Category-D, then there is no additional adjustment of pressure for Exposure Category

Kzt, Topographic factor

H, Height of hill or escarpment	=	27	m	(Grading level)
Lh, Distance upwind of crest at H/2	=	50	m	(shore to escarpment = 100m)
x, Distance from crest to building site	=	100	m	(escarpment to bldg = 100m)
z, Ht above ground surface at bldg site	=	42.75	m	27+ ht of shelter

Considering 2-D escarpments

μ, Horizontal attenuation factor down wind	=	4	Figure 26.8-1 (ASCE 7-10) -
γ, Height attenuation factor	=	2.5	Figure 26.8-1 (ASCE 7-10)
k1, (k1/(H/Lh) = 0.95	=	0.513	
k2,	=	0.5	
k3,	=	0.118	
Kzt, .	=	1.06	
Kd, Wind directionality factor	=	0.85	Table 26.6-1, ASCE 7-10

G - Gust effect factor = 0.85 26.9.1, ASCE 7-10

Level	Height above ground "m"		K_z	K_{zt}	K_d	$q_p(z)$ (kN/m²)	G * $q_p(z)$ (kN/m²)
Level-1	0.00 -	5.00	0.884	1.060	0.850	3.587	3.05
Level-2	5.00 -	10.00	0.994	1.060	0.850	4.033	3.43
Level-3	10.00 -	15.00	1.076	1.060	0.850	4.366	3.71
Level-4	15.00 -	20.00	1.127	1.060	0.850	4.572	3.89
Level-5	20.00 -	25.00	1.174	1.060	0.850	4.763	4.05
Level-6	25.00 -	30.00	1.207	1.060	0.850	4.896	4.16
Level-7	30.00 -	40.00	1.272	1.060	0.850	5.162	4.39
Level-8	40.00 -	50.00	1.316	1.060	0.850	5.339	4.54

Table 5-3 : Wind pressure for height z

C_f - Net force coefficient

Ref: Sec. 4.1, ASCE-Report - Wind Loads and Anchor Bolt Design for Petrochemical Facilities For Structural member = = 1.8

Force on Pipe: F = $q_z x G x C_f x A_f$

Wind Force along X direction: (No sheeting up to 3m)

z, (m)	Member Property	Member depth/ width (m)	Insulation width	wind expose depth / width	F in X Direction (kN/m) (Per frame)
3.00	HE600B	0.600	0.05	0.700	3.84
3.00	HE550A	0.300	0.05	0.400	2.2
3.00	L120X120X12	0.120	0.05	0.220	1.26

Wind Force along Z direction:

z, (m)	Member Property	Member depth/ width (m)	Insulation width	wind expose Depth / width	F in Z Direction (kN/m) (Per frame)
3.00	HE600B	0.300	0.05	0.40	2.2
3.00	HE550A	0.540	0.05	0.64	3.51
3.00	L120X120X12	0.120	0.05	0.220	1.26

WIND LOAD CALCULATIONS (AS PER ASCE-7-10) - FOR ROOF & WALL

Slope of roof

Elevation top of sloped roof	=	15.750	m	
Elevation bottom of sloped roof	=	15.000	m	
Width of roof for slope calculation	=	7.50	m	
Slope of roof, θ	=	5.71 °		
Mean roof height H	=	15.750	m	

Design pressure

Wind Force on Enclosed and Partially Enclosed Buildings

Net Design pressure P	=	$qGC_p - q_i(GC_{pi})$		Eq 27.4-1 of ASCE-7-10

Calculation of qz

Wind speed	=	85.70	m/sec	
Wind directionality factor Kd	=	0.85		Cl 26.9-1 of ASCE-7-10
Topography factor Kzt	=	1.06		Fig 26.8-1, ASCE 7-10
Exposure category	=	D		
Velocity pressure, qz	=	$0.613 \times K_z \times K_{zt} \times K_d \times V^2$		(Eq. 27.3-1), ASCE 7-10
	=	4056.46 x Kz	N/m^2	

Exposure coefficient K_z

Height z,m	K_z	$q_{z,kN/m2}$
15.750	1.084	4.40

Velocity pressure at height z

5 m	=	3.59	kN/m^2
10 m	=	4.03	kN/m^2
15 m	=	4.37	kN/m^2
15.75 m	=	4.40	kN/m^2

Gust factor

Gust factor,G	=	0.85		Cl.26.9.1 of ASCE-7-10
WBS-30.5-Condensate area				
OFF GAS COMPR._SHELTER				
Length of Shelter,L	=	36.0	m	
Width of Shelter,B	=	15.0	m	
Height of opening,Hp	=	3.0	m	
Height of Shelter	=	15.0	m	
Area of Opening,Ao	=	108.0	m²	
Area of Wall, Ag	=	540.0	m²	
Total Gross Area of Wall opening, Aoi	=	738.0	m²	
Total Gross Area -Wall exclude opening,Ai	=	1530	m²	
(Aoi/Agi)	=	0.48		

Condition for Shelter Type (As per Clause 26.1 of ASCE-7-10):

Ao	<	0.8*Ag
Ao	<	1.1*Agi
Ao	>	min(0.37sq.m,0.01Ag)
0.20	<	(Aoi/Agi)

Enclosed Building

Figure 26.11-1, ASCE 7-10

Internal Pressure Coefficient,GC$_{pi}$

CASE A	-0.18
CASE B	0.18

External Pressure Co-efficent for Pitched Free Roofs, Cp

Refer Figure 27.4-1, ASCE 7-10 (reduction Factor = 1.0)

X direction (0°) h/L	=	0.4
Z direction (90°) h/B	=	1
Walls L/B	=	2.4
θ	=	5.71 °

ROOF PRESSURE CO-EFFICIENT		
X direction (Parallel to Ridge)	**Z direction (Normal to Ridge)**	
upto h	upto h/2	>h/2
-0.9	-1.3	-0.70

WALL PRESSURE CO-EFFICIENT	
Windward	0.80
Leeward	-0.30
Side Wall	-0.70

WIND LOAD (WX(+) CASE A Cpi = -0.18)

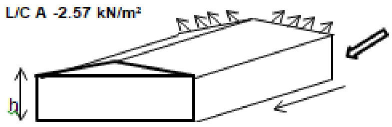
DESIGN PRESSURE FOR ROOF:

Load Case A	Case A for Gcpi = - 0.18 upto h (windward)	qGCp-qi(Gcpi)
Max, kN/m²	-2.57	=4.40 x [(0.85x-0.9)-(-0.18)]

DESIGN PRESSURE FOR WALL:

Cases	Case A for Gcpi = - 0.18			qGCp-qi(Gcpi)
	5m	10m	15m	
Windward,kN/m²	3.08	3.47	3.75	=4.37 x [(0.85x0.8)-(-0.18)]
Leeward,kN/m²	-0.27	-0.30	-0.33	=4.37 x [(0.85x-0.3)-(-0.18)]
Side Wall,kN/m²	-1.49	-1.67	-1.81	=4.37 x [(0.85x-0.7)-(-0.18)]

WIND LOAD ACTING ON ROOF IN X DIRECTION

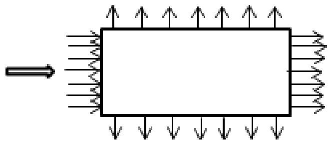


Wind (+) X direction -Load Case A

Load Case A (for Full Length parallel to ridge)

Contributing span (m)	Wind load (kN/m)
3	-7.71
6	-15.42

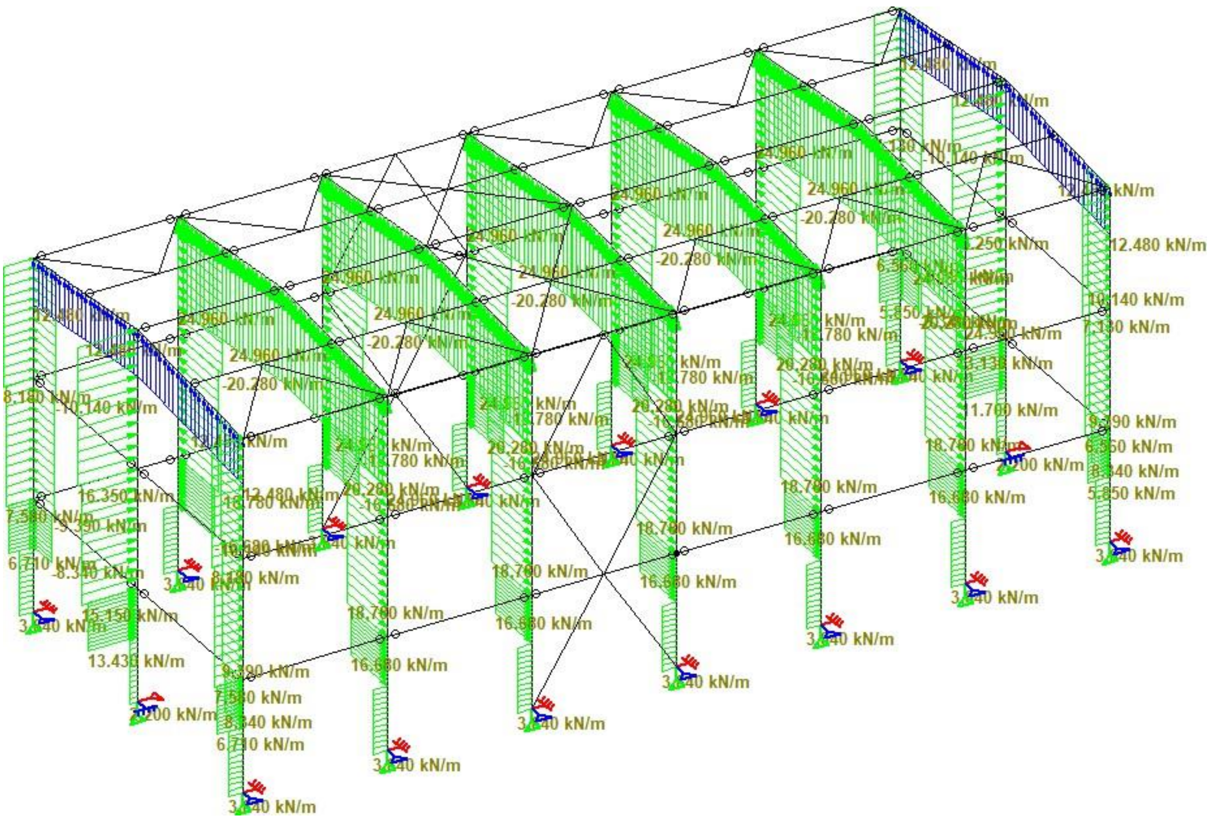
WIND LOAD ACTING IN WALLS



Wind (+) X direction -Load Case A

(+ X direction) Case A

	Contributing span (m)	Wind load (kN/m)		
		5m	10m	15m
Windward	3.75	11.55	13.01	14.06
	7.5	23.10	26.03	28.13
Leeward	3.75	-1.01	-1.13	-1.24
	7.5	-2.03	-2.25	-2.48
Side	6	-8.94	-10.02	-10.86
	3	-4.47	-5.01	-5.43



Wind Load on Structure, Roof and Side Walls along X (+) direction-
Load Case A

WIND LOAD (WX(+) CASE B Cpi = 0.18)

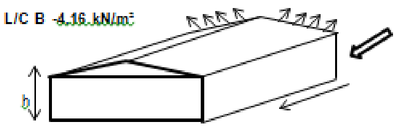
DESIGN PRESSURE FOR ROOF:

Cases	Case B for Gcpi = 0.18 upto h (windward)	qGCp-qi(Gcpi)
Max.kN/m²	-4.16	= 4.40 x [(0.85x-0.9)-(0.18)]

DESIGN PRESSURE FOR WALL:

Cases	Case B for Gcpi = 0.18			qGCp-qi(Gcpi)
	5m	10m	15m	
Windward.kN/m²	1.79	2.02	2.18	= 4.37 x [(0.85x0.8)-(0.18)]
Leeward.kN/m²	-1.56	-1.75	-1.90	= 4.37 x [(0.85x-0.3)-(0.18)]
Side Wall.kN/m²	-2.78	-3.13	-3.38	= 4.37 x [(0.85x-0.7)-(0.18)]

WIND LOAD ACTING IN X DIRECTION



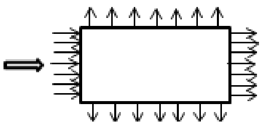
Wind (+) X direction -Load Case B

WIND LOAD ACTING IN X DIRECTION

Load Case B (for Full Length parallel to ridge)

Contributing span(m)	Wind load (kN/m)
3	-12.48
6	-24.96

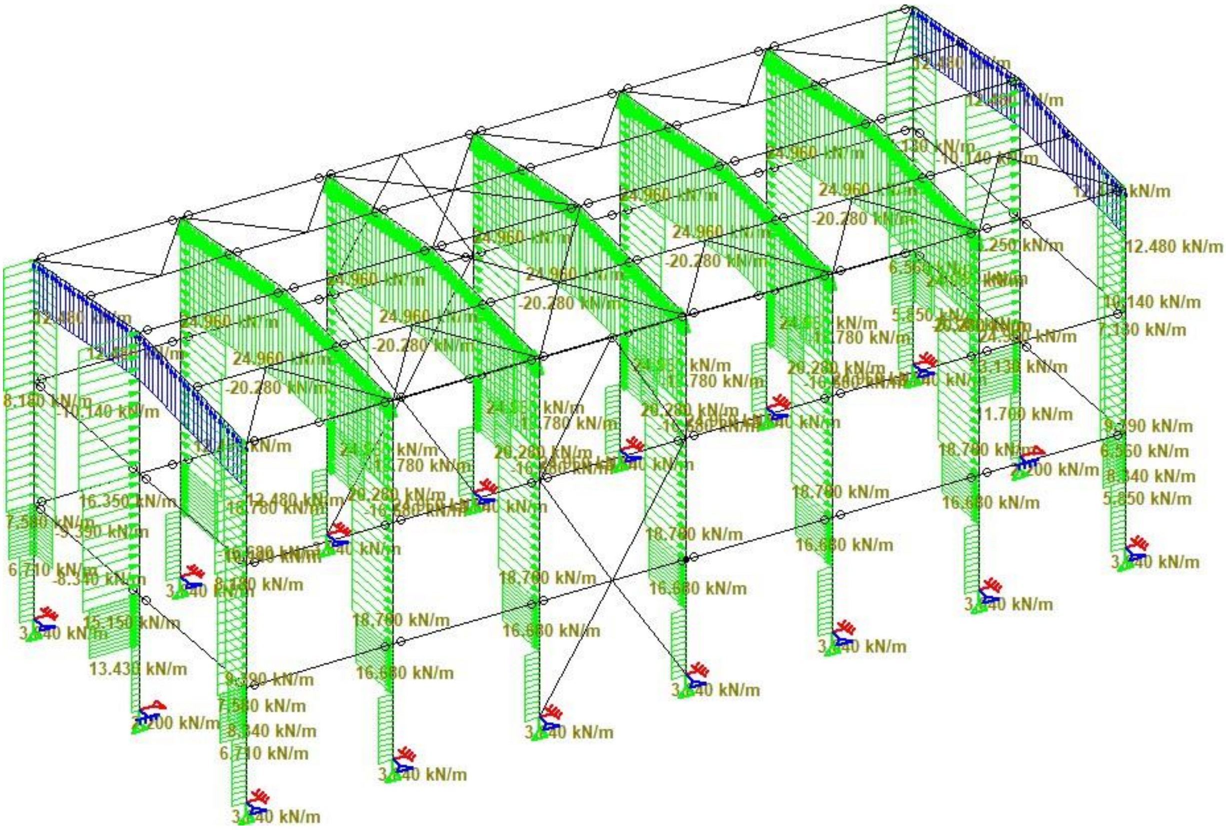
WIND LOAD ACTING IN WALLS



Wind (+) X direction -Load Case B

(+ X direction) Case B

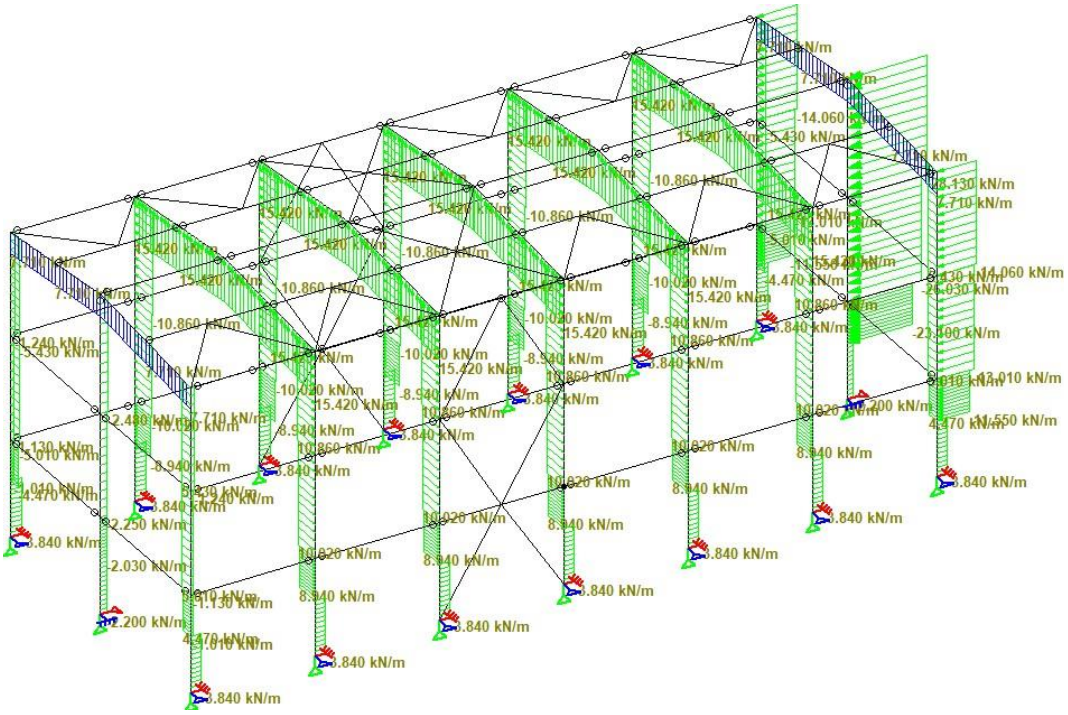
	Contributing span (m)	Wind load (kN/m)		
		5m	10m	15m
Windward	3.75	6.71	7.58	8.18
	7.5	13.43	15.15	16.35
Leeward	3.75	-5.85	-6.56	-7.13
	7.5	-11.70	-13.13	-14.25
Side	6	-16.68	-18.78	-20.28
	3	-8.34	-9.39	-10.14



Wind Load on Structure, Roof and Side Walls along X (+) direction-Load Case B

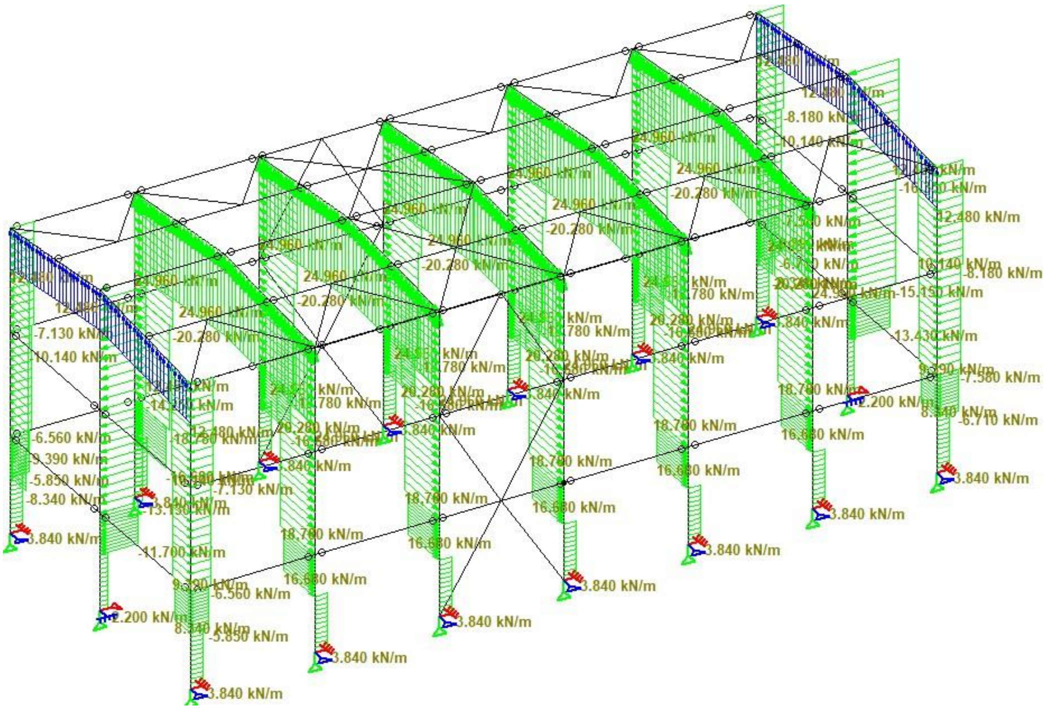
Wind load on WX(-) calculations are same as wind load on WX(+), only direction change has been applied in staad.

WIND LOAD (WX(-) CASE A Cpi = -0.18)



Wind Load on Structure, Roof and Side Walls along X (-) direction-Load Case A

WIND LOAD (WX(-) CASE B Cpi = 0.18)

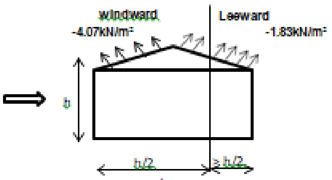


Wind Load on Structure, Roof and Side Walls along X (-) direction-Load Case B

WIND LOAD (WZ(+) CASE A Cpi = -0.18)

DESIGN PRESSURE FOR ROOF:

Cases	Case A for Gcpi = - 0.18	
	upto h/2(windward) = 4.40x[(0.85x-1.3)-(-0.18)]	>h/2(Leeward) = 4.40x[(0.85x-0.7)-(-0.18)]
qGCp-qi(Gcpi) Max kN/m²	-4.07	-1.83



Wind (+)Z direction -Load Case A

Load Case A

Windward net design pressue(upto h/2):

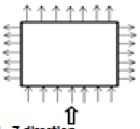
Contributing span(□m)	Wind load ?(kN/m)
3	-12.21
6	-24.42

Leeward net design pressue(> h/2):

Contributing span(□m)	Wind load ?(kN/m)
3	-5.49
6	-10.98

DESIGN PRESSURE FOR WALL:

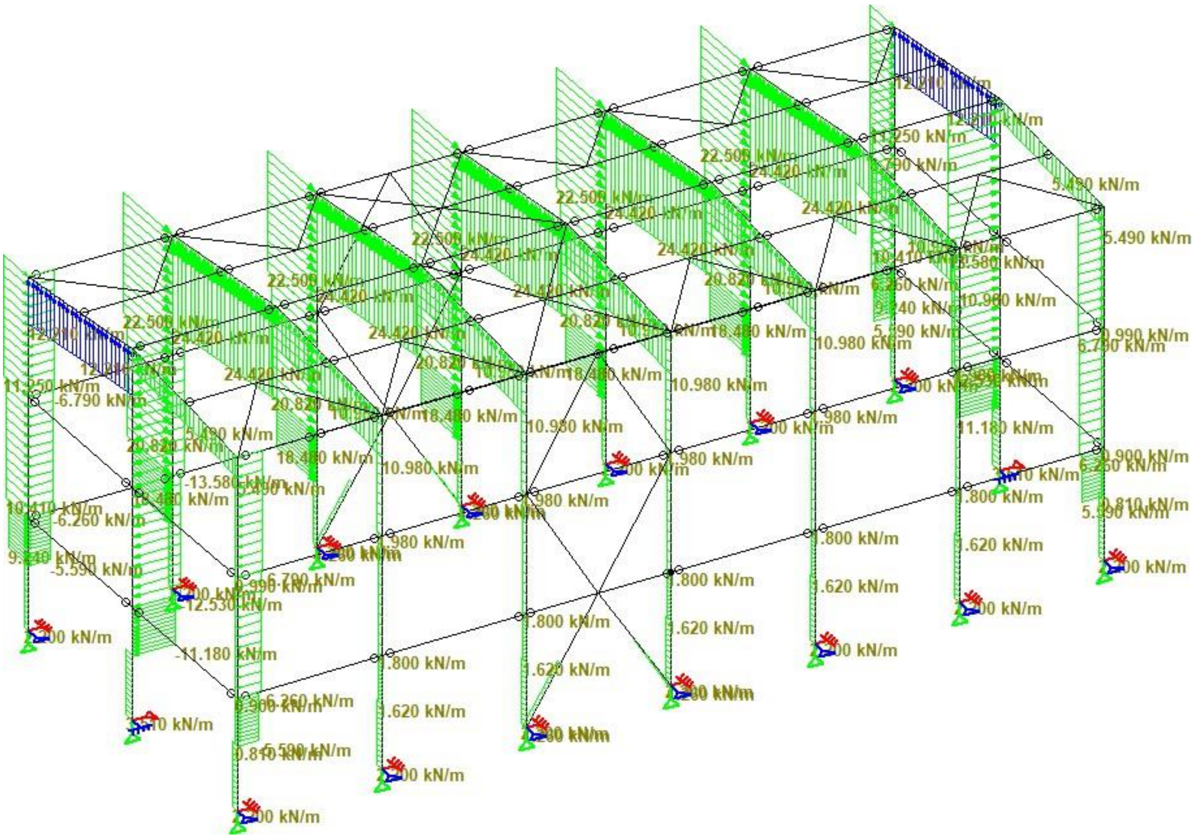
Cases	Case A for Gcpi = -0.18			qGCp-qi(Gcpi)
	5m	10m	15m	
Windward kN/m²	3.08	3.47	3.75	= 4.37 x [(0.85x0.8)-(-0.18)]
Leeward kN/m²	-0.27	-0.30	-0.33	= 4.37 x [(0.85x-0.3)-(-0.18)
Side Wall kN/m²	-1.49	-1.67	-1.81	= 4.37 x [(0.85x-0.7)-(-0.18)



Wind +Z direction

(+ Z direction) Case A

	Contributing span (m)	Wind load ?(kN/m)		
		5m	10m	15m
Windward	6	18.48	20.82	22.50
	3	9.24	10.41	11.25
Leeward	6	-1.62	-1.80	-1.98
	3	-0.81	-0.90	-0.99
Side	3.75	-5.59	-6.26	-6.79
	7.5	-11.18	-12.53	-13.58

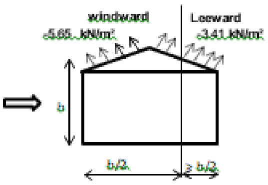


Wind Load on Structure, Roof and Side Walls along Z (+) direction-Load Case A

WIND LOAD (WZ(+) CASE B Cpi = 0.18)

DESIGN PRESSURE FOR ROOF:

Cases	Case A for Gcpi = 0.18	
	upto h/2(windward) = 4.40x[(0.85x-1.3)-(0.18)]	>h/2(Leeward) = 4.40x[(0.85x-0.7)-(0.18)]
Max kN/m²	-5.65	-3.41



Wind (+)X direction -Load Case B

Load Case B

Windward net design pressue(upto h/2):

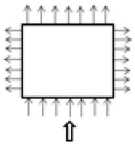
Contributing span(□m)	Wind load (□kN/m)
3	-16.95
6	-33.90

Leeward net design pressue(> h/2):

Contributing span(□m)	Wind load ?(kN/m)
3	10.23
6	20.46

DESIGN PRESSURE FOR WALL:

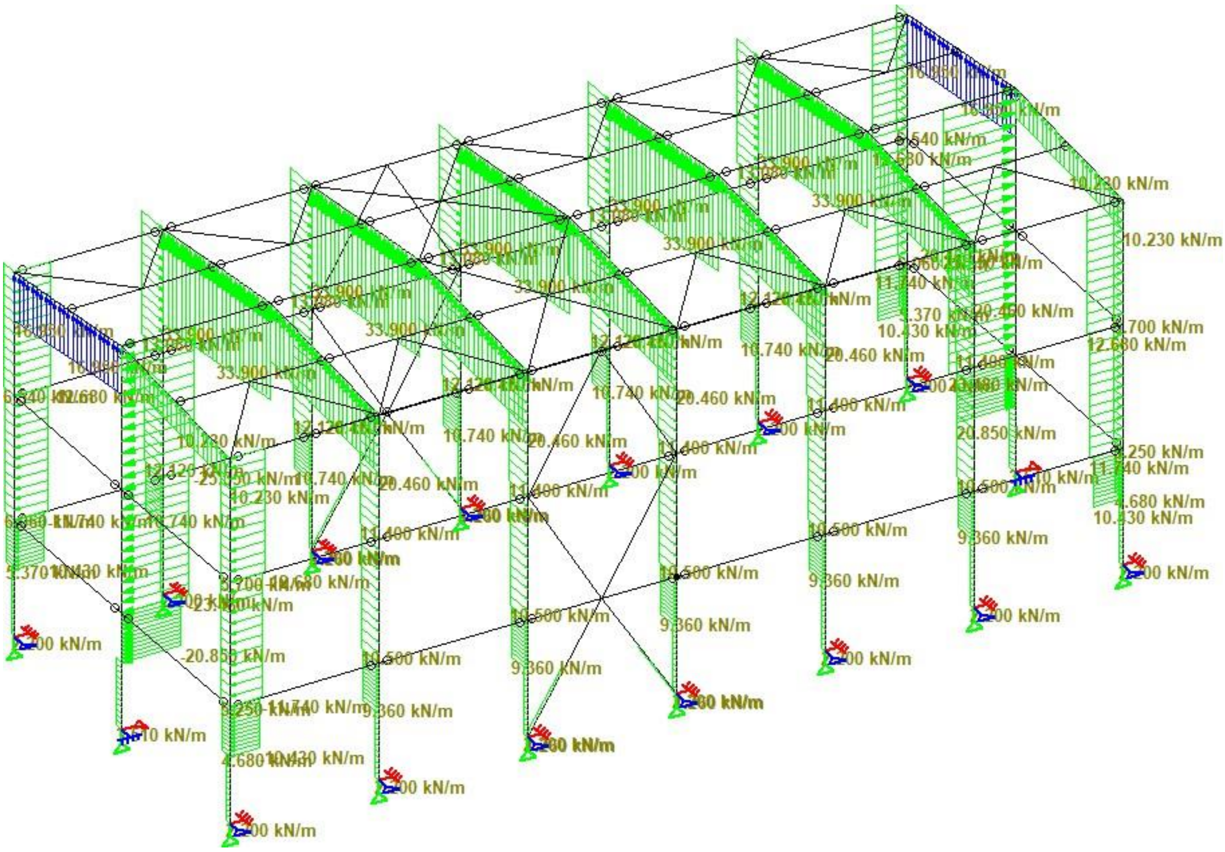
Cases	Case B for Gcpi = 0.18			qGCp-qi(Gcpi)
	5m	10m	15m	
Windward kN/m²	1.79	2.02	2.18	= 4.37 x [(0.85x0.8)-(0.18)]
Leeward kN/m²	-1.56	-1.75	-1.90	= 4.37 x [(0.85x-0.3)-(0.18)]
Side Wall kN/m²	-2.78	-3.13	-3.38	= 4.37 x [(0.85x-0.7)-(0.18)]



Wind +Z direction -

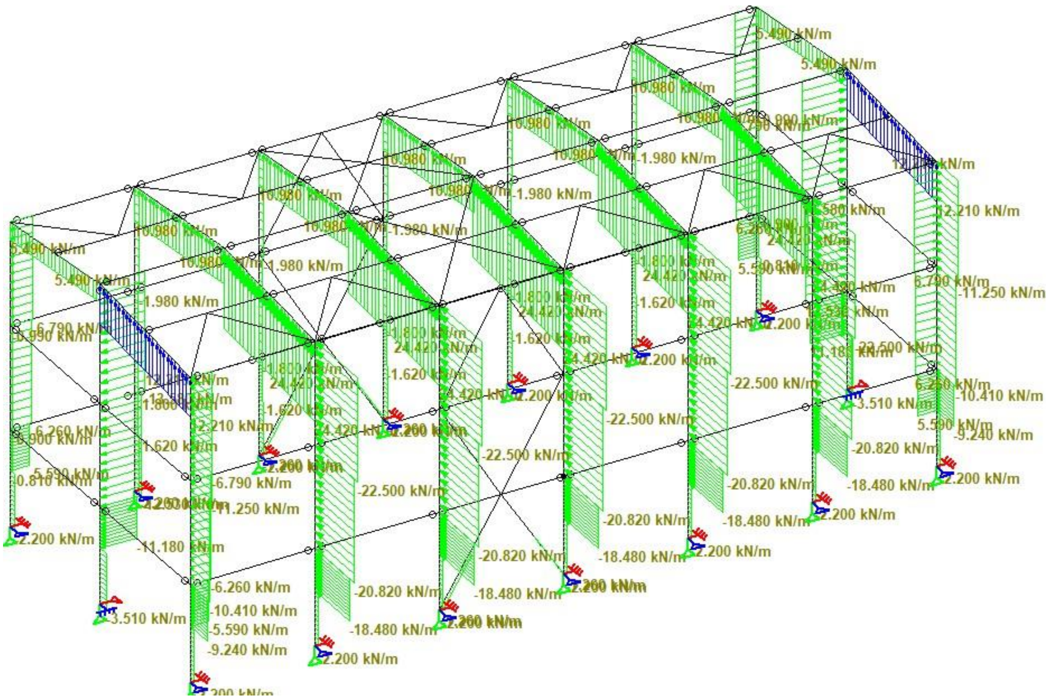
(+Z direction) Case B

	Contributing span (m)	Wind load (kN/m)		
		5m	10m	15m
Windward	6	10.74	12.12	13.08
	3	5.37	6.06	6.54
Leeward	6	-9.36	-10.50	-11.40
	3	-4.68	-5.25	-5.70
Side	3.75	-10.43	-11.74	-12.68
	7.5	-20.85	-23.48	-25.35



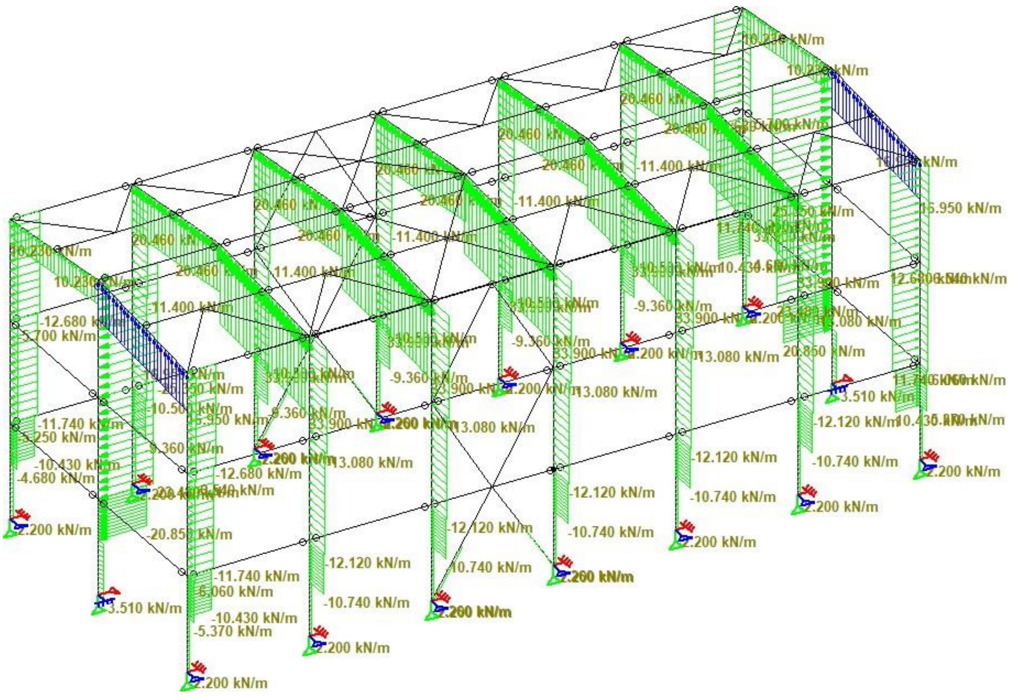
Wind Load on Structure, Roof and Side Walls along Z (+) direction-Load Case B
Wind load on WZ(-) calculations are same as wind load on WZ(+), only direction change has been applied in staad.

WIND LOAD (WZ(-) CASE A Cpi = -0.18)



Wind Load on Structure, Roof and Side Walls along Z (-) direction-Load Case A

WIND LOAD (WZ(-) CASE B Cpi = 0.18)



Wind Load on Structure, Roof and Side Walls along Z (-) direction-Load Case B

20. SEISMIC LOAD (EX/EZ/EY)

The Site-Specific Design Response Spectrum shall be considered from Section 6.7 of project document "Design Specification for Loads and Load Combinations"

Risk Factor	=	III	Table 1.5-1/ASCE-7-10
Importance Factor, I	=	1.25	Table 1.5-2/ASCE-7-10
Seismic Design Category	=	B	Table 11.6-1/ASCE-7-10

Response modification coefficient, R

Steel ordinary concentrically braced frame X-Dir	=	3.25	Table 12.2-1/ASCE-7-10
Steel ordinary moment frames Z-Dir	=	3.5	Table 12.2-1/ASCE-7-10

For initial Staad factor in X Dir I/R	0.38	
For initial Staad factor in Z Dir I/R	0.39	(I/R increased to satisfy shear enhancement)

Spectral Acceleration Parameters for 5% DBE_R Spectrum for Vs = 300m/s

S_{DS} = 0.3 g (Table 6-T=0.2sec)

Site specific acceleration at time period 1 sec & 2 sec are,

S_{a1} = 0.126 g

S_{a2} = 0.063 g (Table 6-T=1sec & T=2sec)

S_{D1} = max (S_{a1}, 2 x S_{a2}) Eq.11.4-1/ASCE-7-10

S_{D1} = 0.126 g Eq.11.4-2/ASCE-7-10

T_o = 0.2 x (S_{D1}/S_{DS}) Cl: 11.4.5/ASCE 7-10

= 0.084 s

Ts = S_{D1}/S_{DS} Cl: 11.4.5/ASCE 7-10

Ts = 0.42 s

TL = 12 s (Cl. 6.7 of project specification)

Seismic design forces are to be combined by orthogonal combination procedure, i.e. 100 % in one orthogonal irection along with 30 % in other orthogonal direction — Cl.12.5.3a/ ASCE 7-10

Equivalent Lateral Force Procedure

V, Seismic Base Shear = $C_s W$

C_s, Seismic response coefficient = $\dfrac{S_{DS}}{(R/I)}$

C_s Steel ordinary concentrically braced frame X-Dir = **0.116**

C_s Steel ordinary moment frames Z-Dir = **0.108**

Time Period calculated from STAAD :

Time Period for Brace Frame X d	Tstaad	=	0.38	sec	mode shape	5
Time Period for Moment Frame Z	Tstaad	=	0.83	sec	mode shape	1

For Time Period less than or equal to Long Period Transition Period T_L

$T \le T_L$ $C_s = (S_{D1}/((R/I)*T)$ Eq.12.8-3/ASCE-7

C_s, Seismic response coefficient = $\dfrac{(S_{D1})}{T*(R/I)}$

C_s Steel ordinary concentrically braced frame X-Dir = **0.1280**

C_s Steel ordinary moment frames Z-Dir = **0.0550**

For Time Period greater than Long Period Transition Period T_L

$T > T_L$ $C_s = (S_{D1}*T_L)/T^2*(R/I)$ Eq.12.8-4/ASCE-7

C_s, Seismic response coefficient	=	$\frac{(S_{D1}*T_L)}{T^2*(R/I)}$		
C_s along frame in X-Dir	=	4.0280		
C_s along frame in Z-Dir	=	0.7840		
Minimum C_s, Seismic response coefficient	=	$0.044S_{DS}*I \geq 0.01$		Eq.12.8-5/ASCE-7
	=	0.0165	>	0.01
C_s, along frame in X dir	=	0.1280	>	0.1160
C_s, along frame in Z dir	=	0.0550	<	0.1080

Hence actual value of Cs

C_s, along frame in X dir	=	0.1160
C_s, along frame in Z dir	=	0.0550

Operating condition

The Seismic weight, includes the weight of structure, equipment loads and operating loads.

Redundancy Factor ρ		=	1	12.3.4.1/ASCE-7	
Total weight (D)		=	2152	kN	(from Staad)
Base shear along xdir	(2152x0.116)	=	249.63	kN	(C_sW)
Base shear along Zdir	(2152x0.055)	=	118.36	kN	(C_sW)

CALCULATION OF BASE SHEAR

The Seismic weight W, includes the weight of structure,equipment loads and operating load

W, Total weight	=	2152	kN
For X			
V,Base shear along frame X Dir	=	249.63	kN
Enhanced Base shear including ρ & Ω_0	=	249.63	kN
Comparison with STAAD			
V,Base shear along frame X Dir	=	219.2	kN
For Z			
V,Base shear along frame Z Dir	=	118.36	kN
Enhanced Base shear including ρ & Ω_0	=	118.36	kN
Comparison with STAAD			
V,Base shear along frame Z Dir	=	107	kN

Next Iteration

0.85 V, Base shear along Frame in X dir = 212.19 kN 12.9.4/ ASCE 7

= 0.968 <1 Shear enhancement Not required

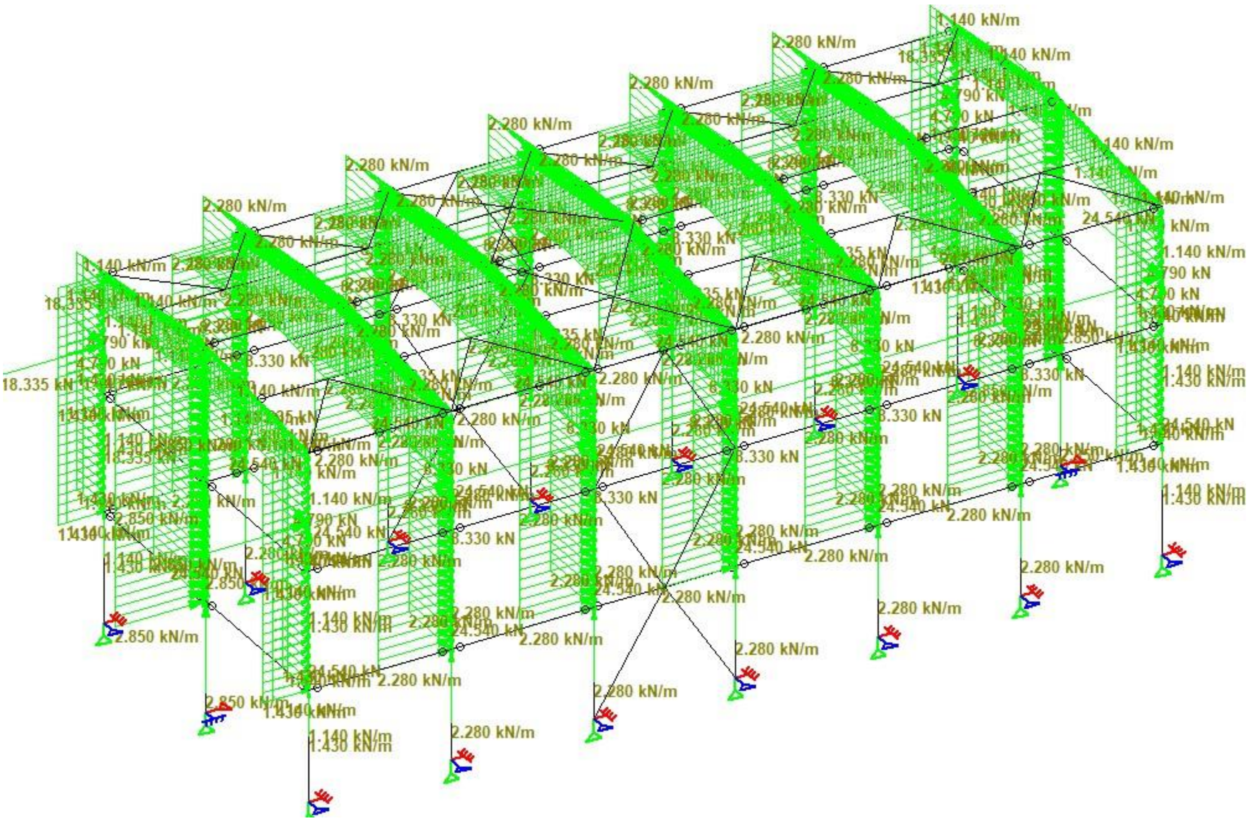
Next Iteration

0.85 V, Base shear along Frame in Z dir = 100.61 kN 12.9.4/ ASCE 7

= 0.940 =<1 Shear enhancement Not required

Vertical load effect on structure

Ev, Vertical earthquake load effect	=	$0.2*S_{DS}*D$		Eq.12.4-4/ASCE-7
Vertical load effect on structure	=	129.12	kN	



Seismic load in X/Z/Y – Direction

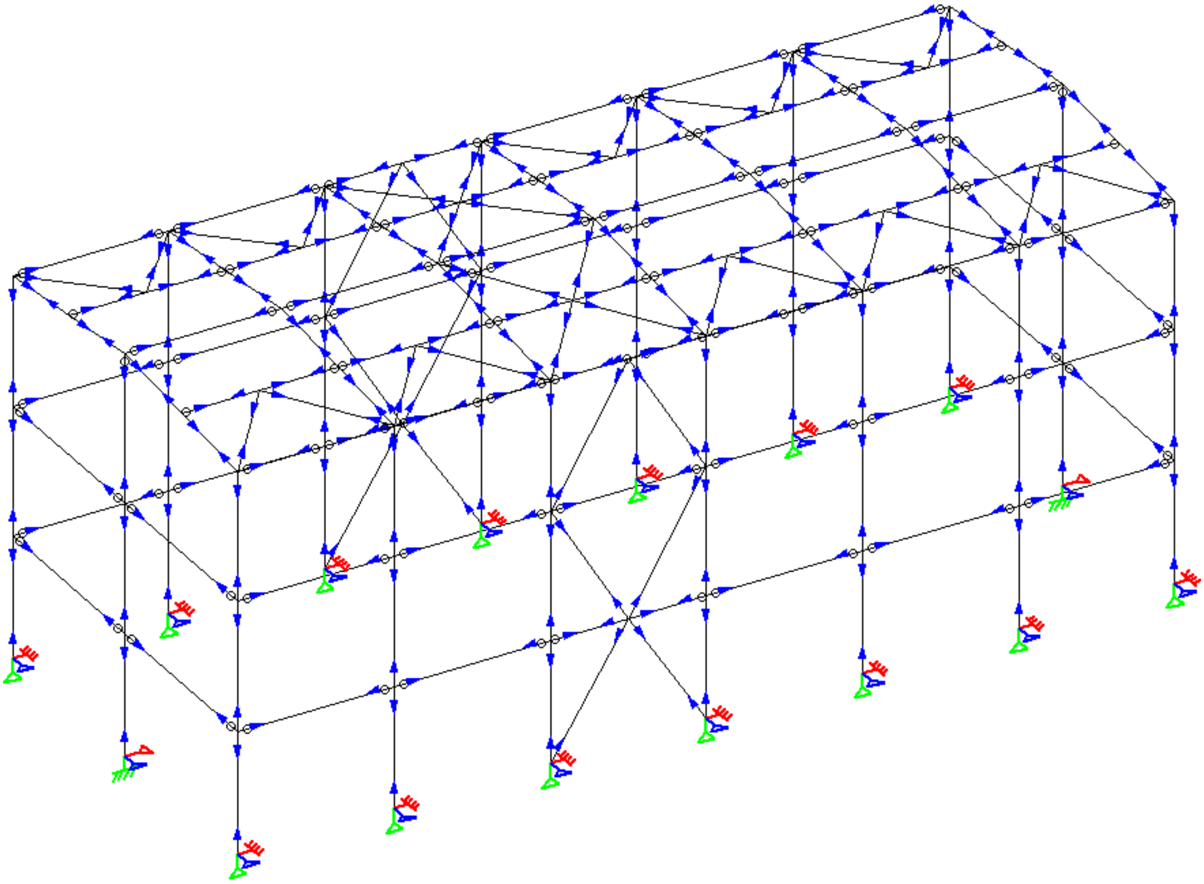
21. THERMAL LOAD (Ts1 & Ts2)

Temperature load is considered as per Section 6.5 of "Basic Engineering Design Data (BEDD) Onshore

The thermal load for the structure is considered for the maximum temperature variation of +42°C and minimum temperature variation of 6°C from the ambient temperature.

Maximum Temperature : 42°C
Minimum Temperature : 6°C Mean Ambient Temperature : 26°C

TS1 max = 42 – 26 = +16 °C TS2 min = 6 – 26 = - 20 °C



22. SERVICIABILITY LOAD COMBINATION

S.no	Buildings and Open Frame Structures Specific Load Combination	Description
1	Ds + Ts	Dead Weight + Sustained Thermal (Sustained Load Case for Deflection or Settlement)
2	Ds + Ts + L	Dead Weight + Sustained Thermal + Live
3	N/A	
4	Ds + Ts + 0.75 L + 0.75 Lr	Dead Weight + Sustained Thermal + Live + Roof Live
5	Ds + Ts + 0.6 W	Dead Weight + Sustained Thermal + Wind
	Ds + Ts + E*	Dead Weight + Sustained Thermal + Earthquake
6a	Ds + Ts + 0.75 L + 0.75 (0.6 W) + 0.75 Lr	Dead Weight + Sustained Thermal + Live + Wind + Roof Live
6b	Ds + Do + Ts + 0.75 L + 0.75 E*	Dead Weight + Sustained Thermal + Live + Earthquake

7	0.6 (Ds) + Ts + 0.6 W	Dead Weight + Sustained Thermal + Wind (Wind Uplift Case)
8	0.6 (Ds) + Ts + E*	Dead Weight + Sustained Thermal + Earthquake (Earthquake Uplift Case)

*Deflection shall be computed using the strength level seismic forces as specified in Section 12.8 of ASCE 7-10 without reduction for allowable stress design.

Load	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Comb	DS	L1	L2	LR	WX1 (+)	WX2 (+)	WX1 (-)	WX2 (-)	WZ1 (+)	WZ2 (+)	WZ1 (-)	WZ2 (-)	EX	EZ	EY	TS 1	TS2
101	1															1	
102	1																1
103	1	1	1													1	
104	1	1	1														1
105	1			1												1	
106	1			1													1
107	1	0.75	0.75	0.75												1	
108	1	0.75	0.75	0.75													1
109	1				0.6											1	
110	1					0.6										1	
111	1						0.6									1	
112	1							0.6								1	
113	1								0.6							1	
114	1									0.6						1	
115	1										0.6					1	
116	1											0.6				1	
117	1				0.6												1
118	1					0.6											1
119	1						0.6										1
120	1							0.6									1
121	1								0.6								1
122	1									0.6							1
123	1										0.6						1
124	1											0.6					1
125	1												1	0.3	1	1	
126	1												0.3	1	1	1	
127	1												-1	-0.3	1	1	
128	1												-0.3	-1	1	1	
129	1												1	0.3	1		1
130	1												0.3	1	1		1
131	1												-1	-0.3	1		1
132	1												-0.3	-1	1		1

133	1	0.75		0.75	0.45											1	
134	1	0.75		0.75		0.45										1	
135	1	0.75		0.75			0.45									1	
136	1	0.75		0.75				0.45								1	
137	1	0.75		0.75					0.45							1	
138	1	0.75		0.75						0.45						1	
139	1	0.75		0.75							0.45					1	
140	1	0.75		0.75								0.45				1	
141	1	0.75		0.75	0.45												1
142	1	0.75		0.75		0.45											1
143	1	0.75		0.75			0.45										1
144	1	0.75		0.75				0.45									1
145	1	0.75		0.75					0.45								1
146	1	0.75		0.75						0.45							1
147	1	0.75		0.75							0.45						1
148	1	0.75		0.75								0.45					1
149	1	0.75											0.75	0.23	0.75	1	
150	1	0.75											0.23	0.75	0.75	1	
151	1	0.75											-0.75	-0.23	0.75	1	
152	1	0.75											-0.23	-0.75	0.75	1	
153	1	0.75											0.75	0.23	0.75		1
154	1	0.75											0.23	0.75	0.75		1
155	1	0.75											-0.75	-0.23	0.75		1
156	1	0.75											-0.23	-0.75	0.75		1
157	0.6				0.6											1	
158	0.6					0.6										1	
159	0.6						0.6									1	
160	0.6							0.6								1	
161	0.6								0.6							1	
162	0.6									0.6						1	
163	0.6										0.6					1	
164	0.6											0.6				1	
165	0.6				0.6												1
166	0.6					0.6											1
167	0.6						0.6										1
168	0.6							0.6									1
169	0.6								0.6								1
170	0.6									0.6							1
171	0.6										0.6						1
172	0.6											0.6					1
173	0.6												1	0.3	1	1	
174	0.6												0.3	1	1	1	
175	0.6												-1	-0.3	1	1	

176	0.6												-0.3	-1	1	1	
177	0.6												1	0.3	1		1
178	0.6												0.3	1	1		1
179	0.6												-1	-0.3	1		1
180	0.6												-0.3	-1	1		1

23. STRENGTH LOAD COMBINATION

S.no	Buildings and Open Frame Structures Specific Load Combination	Description
1	1.4 Ds + 1.2 Ts	Dead Weight + Sustained Thermal
2	1.2 Ds + 1.2 Ts +1.6 L + 0.5 Lr	Dead Weight + Sustained Thermal + Live + Roof Live
3	1.2 Ds + 1.2 Ts + 1.6 Lr + L	Dead Weight + Sustained Thermal + Roof Live + Live
	1.2 Ds + 1.2 Ts + 1.6 Lr + 0.5 W	Dead Weight + Sustained Thermal + Roof Live + Wind
4	1.2 Ds + 1.2 Ts + 1.0 W + L + 0.5 Lr	Dead Weight + Sustained Thermal + Wind + Live + Roof Live
5	1.2 Ds + 1.2 Ts + 1.0 E + 0.5 L	Dead Weight + Sustained Thermal + Earthquake + Live
6	0.9 Ds + 1.2 Ts + 1.0 W	Dead Weight + Sustained Thermal + Wind (Wind Uplift Case)
7	0.9 Ds + 1.2 Ts + 1.0 E	Dead Weight + Sustained Thermal + Earthquake (Earthquake Uplift Case)

Load	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Comb	DS	L1	L2	LR	WX1 (+)	WX2 (+)	WX1 (-)	WX2 (-)	WZ1 (+)	WZ2 (+)	WZ1 (-)	WZ2 (-)	EX	EZ	EY	TS1	TS2
201	1.4															1.2	
202	1.4																1.2
203	1.2	1.6	1.6	0.5												1.2	
204	1.2	1.6	1.6	0.5													1.2
205	1.2	1	1	1.6												1.2	
206	1.2	1	1	1.6													1.2
207	1.2			1.6	0.5											1.2	
208	1.2			1.6		0.5										1.2	
209	1.2			1.6			0.5									1.2	
210	1.2			1.6				0.5								1.2	
211	1.2			1.6					0.5							1.2	

212	1.2			1.6						0.5						1.2	
213	1.2			1.6							0.5					1.2	
214	1.2			1.6								0.5				1.2	
215	1.2			1.6	0.5												1.2
216	1.2			1.6		0.5											1.2
217	1.2			1.6			0.5										1.2
218	1.2			1.6				0.5									1.2
219	1.2			1.6					0.5								1.2
220	1.2			1.6						0.5							1.2
221	1.2			1.6							0.5						1.2
222	1.2			1.6								0.5					1.2
223	1.2	1		0.5	1											1.2	
224	1.2	1		0.5		1										1.2	
225	1.2	1		0.5			1									1.2	
226	1.2	1		0.5				1								1.2	
227	1.2	1		0.5					1							1.2	
228	1.2	1		0.5						1						1.2	
229	1.2	1		0.5							1					1.2	
230	1.2	1		0.5								1				1.2	
231	1.2	1		0.5	1												1.2
232	1.2	1		0.5		1											1.2
233	1.2	1		0.5			1										1.2
234	1.2	1		0.5				1									1.2
235	1.2	1		0.5					1								1.2
236	1.2	1		0.5						1							1.2
237	1.2	1		0.5							1						1.2
238	1.2	1		0.5								1					1.2
239	1.2	1											1	0.3	1	1.2	
240	1.2	1											0.3	1	1	1.2	
241	1.2	1											-1	-0.3	1	1.2	
242	1.2	1											-0.3	-1	1	1.2	
243	1.2	1											1	0.3	1		1.2
244	1.2	1											0.3	1	1		1.2
245	1.2	1											-1	-0.3	1		1.2
246	1.2	1											-0.3	-1	1		1.2
247	0.9				1											1.2	
248	0.9					1										1.2	
249	0.9						1									1.2	
250	0.9							1								1.2	
251	0.9								1							1.2	
252	0.9									1						1.2	
253	0.9										1					1.2	
254	0.9											1				1.2	

255	0.9				1												1.2
256	0.9					1											1.2
257	0.9						1										1.2
258	0.9							1									1.2
259	0.9								1								1.2
260	0.9									1							1.2
261	0.9										1						1.2
262	0.9											1					1.2
263	0.9												1	0.3	1	1.2	
264	0.9												0.3	1	1	1.2	
265	0.9												-1	-0.3	1	1.2	
266	0.9												-0.3	-1	1	1.2	
267	0.9												1	0.3	1		1.2
268	0.9												0.3	1	1		1.2
269	0.9												-1	-0.3	1		1.2
270	0.9												-0.3	-1	1		1.2

24. UNITY CHECK

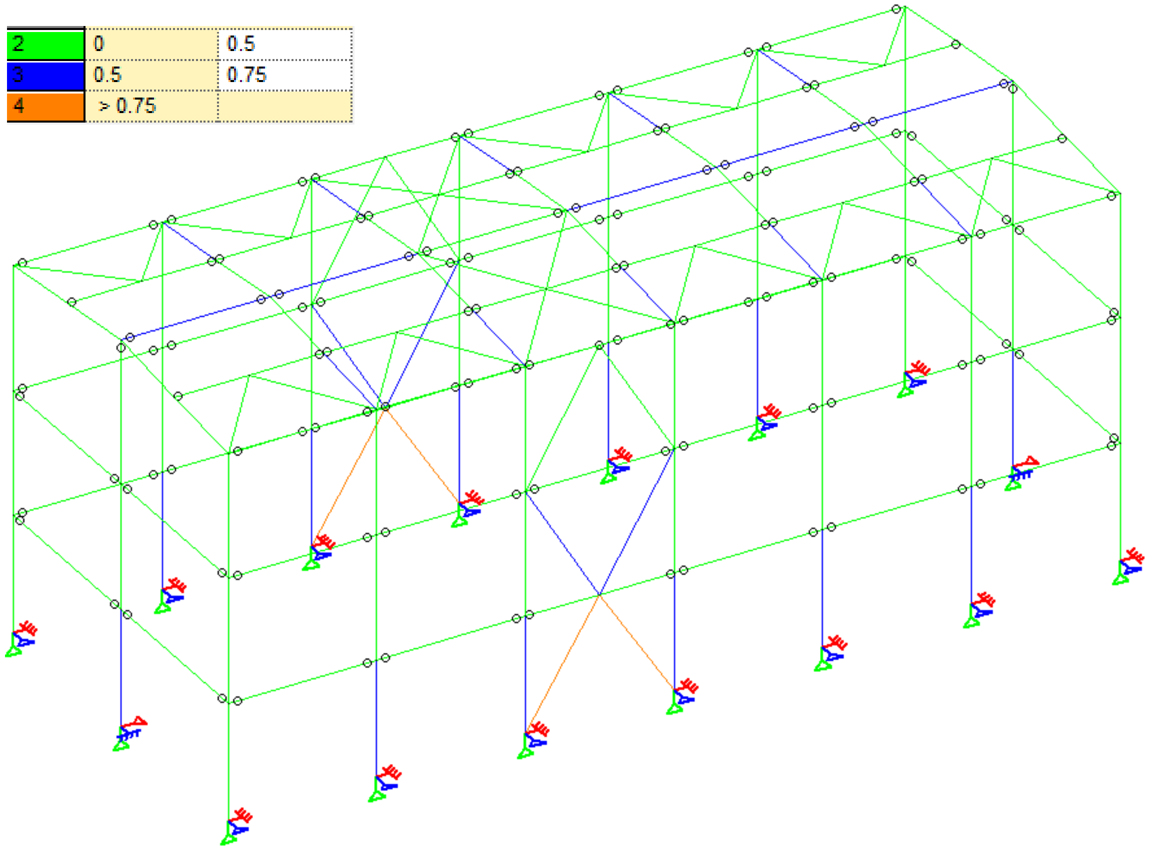
Design of the structure is performed using STAAD software and ensured member design adequacy. The unity ratios of the members are presented below.

Strength Case:

Member Description	Beam No.	Member Property	Load Combination	UC Ratio	Allowable Ratio
Column	7	HE600B*	261	0.65	0.9
Cable End Column	200	HE500A*	233	0.68	0.9
Rafter Beam	43	HE450A*	262	0.65	0.9
Longitudinal Tie Beam	31	HE160A	231	0.59	0.9
Vertical Bracing	65	L120X120X12 SD	225	0.81	0.81
Horizontal Bracing	93	L90X90X10 SD	223	0.39	0.80

*Member Size are governed by Deflection criteria refer. Section 6.2.1

Unity Stress ratio



25. BASE REACTION

L/C	Horizontal	Vertical	Horizontal	Moment		
	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
1 DEAD LOAD (DS)	0	2269	0	20	0	0
2 LIVE LOAD(L1)	0	207	0	0	0	0
3 CRANE IMPACT LOAD (L2)	13	700	110	1196	0	1
4 ROOF LIVE LOAD (LR)	0	315	0	0	0	0
5 WIND LOAD (WX(+) CASE A CPI = -0.18)	-869	-1395	0	0	0	814
6 WIND LOAD (WX(+) CASE B CPI = 0.18)	-869	-2258	0	0	0	815
7 WIND LOAD (WX(-) CASE A CPI = -0.18)	869	-1395	0	0	0	-817
8 WIND LOAD (WX(-) CASE B CPI = 0.18)	869	-2258	0	0	0	-815
9 WIND LOAD (WZ(+) CASE A CPI = -0.18)	0	1601	-1770	-11093	0	1
10 WIND LOAD (WZ(+) CASE B CPI = 0.18)	0	2458	-1770	-11034	0	2
11 WIND LOAD (WZ(-) CASE A CPI = -0.18)	0	1601	1770	11093	0	1
12 WIND LOAD (WZ(-) CASE B CPI = 0.18)	0	2458	1770	11034	0	2
13 SEISMIC LOAD (EX)	224	913	7	33	0	40
14 SEISMIC LOAD (EZ)	5	67	113	948	0	0
15 SEISMIC LOAD (EY)	0	124	0	0	0	0
16 SUSTAINED THERMAL LOAD (TS MAX)	0	0	0	0	0	3
17 SUSTAINED THERMAL LOAD (TS MIN)	0	0	0	0	0	-3

: Base Reaction

Industrial Shelter Design Calculation,
Structural Design of Industrial Sheds,
Industrial Shelter Engineering Design,
How to Design Industrial Structures,
Industrial Shelter Load Calculation,
Wind Load Design for Industrial Shelters,
Seismic Design for Industrial Structures,
Steel Structure Design for Industrial Shelters,
Industrial Shed Foundation Design,
Industrial Shelter Structural Analysis,
Pre-Engineered Industrial Shelter Design,
Live and Dead Load Calculation for Industrial Structures,
Roof Truss Design for Industrial Shelters,
Industrial Shed Beam and Column Design,
IS Code for Industrial Shed Design,
Steel Frame Design for Industrial Buildings,
Lightweight Industrial Shelter Structure,
Cost-Effective Industrial Shed Design,
Industrial Shelter with Crane Load Design,
Industrial Shed Design Software Tools,

PEB Shelter Design Calculation,
Pre-Engineered Building Structure Design,
PEB Shelter Structural Analysis,
Steel PEB Shelter Design Guide,
Wind Load Calculation for PEB Shelters,
Seismic Design for PEB Structures,
PEB Roof Design and Load Calculation,
PEB Column and Beam Design,
Pre-Engineered Industrial Shelter Design,
Foundation Design for PEB Structures,
PEB Building Load Calculation,
IS Code for PEB Shelter Design,
Crane Load Design in PEB Structures,
PEB Truss Design Calculation,
Lightweight PEB Shelter Structures,
Structural Steel Design for PEB Shelters,
Pre-Engineered Shelter Cost Optimization,
Roof Sheeting Design for PEB Buildings,
PEB Shelter with Mezzanine Design,
PEB Shelter Design Software Tools,

Steel Shelter Design AISC 360,
AISC 360 Steel Structure Design,
Steel Shelter Structural Calculation,
Design of Steel Shelter as per AISC Code,

**AISC 360 Structural Design Guide,
Steel Shelter Load Calculation AISC 360,
Wind Load Design for Steel Shelters AISC,
Seismic Design of Steel Shelters AISC 360,
Steel Roof Truss Design AISC Code,
AISC 360 Beam and Column Design,
Foundation Design for Steel Shelters AISC,
Steel Shelter Connection Design AISC 360,
Crane Load Design for Steel Shelters AISC,
Structural Stability Check AISC 360,
Lightweight Steel Shelter Design AISC,
AISC 360 Code for Steel Shelter Analysis,
Steel Frame Shelter Design Calculation,
Roof Sheeting and Purlin Design AISC 360,
Industrial Steel Shelter Design AISC Code,
AISC 360 Software for Steel Design,**